AUTONOMOUS AERIAL ROBOTS IN SURVALANCE APPLICATION

Pavel Haintz, Engineering Science, Simon Fraser University
Ryan Sadler, Engineering Science, Simon Fraser University
Kobus Barnard, Computing Science, UC Berkeley

ABSTRACT

Surveillance task can potentially be assisted with the use of autonomous aerial vehicles. This approach would result in the mission being accomplished more quickly and more effectively resulting in an overall lower mission cost, as well as providing many options to go where it would be hazardous for a manned operation like a nuclear disaster, biological disaster or hostile territory. The Aerial Robotics Group at Simon Fraser University is currently developing autonomous vehicle systems to be used in the International Aerial Robotics Competition where the main goal is to accomplish a surveillance mission.

1. INTRODUCTION

The International Aerial Robotics Competition is a very challenging contest whose completion requires developing a number of technologies to accomplish the given mission. In the competition, all vehicle control must be autonomous (i.e., no human intervention is allowed once the start button has been pushed). The vehicles must fly 3 km, identify a target building, enter it and return pictures back to the starting point. The entry may be accomplished by a secondary vehicle with the restriction that it must arrive or be delivered by air to the site.

2. SYSTEM OVERVIEW

The ARG has focussed on using small vehicles to accomplish the mission. We are developing a system base on a 60 size airplane and a 60 size helicopter. Both of our vehicles are glow fuel powered, this gives us an excellent power to weight ratio and eliminates the electrical noise problems with spark ignition engines. Our goal is to investigate both approaches to the main mission.

3. HELICOPTER

Our first vehicle for this year competition is a helicopter, the main advantages of a helicopter are:

- Ability to hover (this is the single most important advantage of a helicopter)
- It is very compact for transport
- It can be deployed from almost anywhere

The ability to hover however comes at some disadvantages:

- Dangerous rotor blades (this is reduced as much as possible by using a small nitro methane 60 size helicopter that is much smaller than some of the gasoline helicopters)
- Less efficient in flight than an airplane
- Control system complexity

Figure 1: Autonomous Helicopter

Our helicopter features a built-in safety system, operating on an independent power supply. It contains a multiplexing control circuit that can switch to manual control on operator demand. All control systems can thus be controlled by a standard R/C system. The engine can be shut down using one of the R/C channels. This system is powered by two sets of batteries in case the one of the batteries or switches fail and is completely isolated from the main onboard computer system.

The helicopter video system uses an onboard video frame grabber, this allows us to send the high quality digital pictures over our high speed wireless ethernet link. Since the helicopter has the ability to hover the vision processing can be much slower than on an airplane that is constantly moving. Our goal is to make the vision system onboard the helicopter as much as possible, only sending pictures back to the base station that require viewing for the last part of the mission (i.e. identify the control panel inside the nuclear reactor control room).

In Table 1 below is a summary of the Helicopter Specifications

Table 1: Helicopter Specifications

Section		Specification
Mechanics	Airframe	TSK Mystar 60
Weight	Empty weight	5 kg
	Payload capacity	5 kg
	Maximum takeoff weight	10 kg.
Size	Length	1.4 m
	Height	0.47 m
	Main Rotor	MS FAI Pro 710 mm
	Tail Rotor	MS 102 mm
Performance	Max. Speed (est.)	60 km/h
	Max. endurance (est.)	15 min
Propulsion	Engine	YS60 – STII
	Power	2.3 hp @ 16000 rpm
Avionics and Sensors	Computer system	Jumptec P166MMX MOPSlcd6 PC/104+ Frame Grabber
	DGPS	NovAtel RT-2
	3D Sensor	Tokin MDP-A3U7 3D Motion Sensor unit
	Communication	Wireless Ethernet
	Ultrasound Sensors	Polaroid
	Camera	Board level CCD video camera

3.1. SOFTWARE SYSTEM

The navigation, guidance and control processes all run on the helicopter computer, the ground station is used mainly to monitor the operation of the helicopter and view the transmitted images. The operating system onboard the helicopter is real-time embedded Linux. Table 2 below briefly describes each of the system components

Table 2: Helicopter Software System

Component	Purpose
Command	The highest level of control in the system. Its main responsibility is to determine what the helicopter should be doing based on what's happening on and around the helicopter. Because of its important role, the controller has the capability of talking to all other server processes, namely the vision system, the navigation sensor system and the navigation system.

Navigation	The navigation sensor system gets information from the navigation sensors and makes the data available to the rest of the system. Adaptive filters are used to combine the sensor data.
Guidance	Gets information from Command and Navigation and generates the flight path that the helicopter should fly.
Control	The lowest level of control in the system. Gets information from the Guidance system and controls the flight surfaces. We are going to start out with a simple PID based control system and then move onto a fuzzy logic combined with modern control theory approach.

4. AIRPLANE

We are also continuing development of our airplane from previous competitions. The mission of the airplane is to accomplish the autonomous flight with as simple a vehicle as possible.

Figure 2: Autonomous Airplane

The design goal for the airplane was to provide a simple, disposable, flying platform, which in the event of a crash could be easily and quickly replaced.

The airplane also features the same isolated over-ride safety system as the helicopter, which allows a human pilot to take over control of the airplane if required.

In Table 3 below is a summary of the airplane specifications.

Table 3: Airplane Specifications

Section		**Specification**
Weight	Empty weight	3.5-kg
	Payload capacity	2.2-kg
	Maximum takeoff weight	5.7-kg.
Size	Wing Span	1.8 m
	Wing Area	0.57 sq. m
	Length	1.4 m
Performance	Stall Speed (est.)	15 km/h
	Max. Speed (est.)	50 km/h
	Max. Endurance (est.)	20 minutes
Airframe	Airframe materials	Plywood, balsa
	Covering	MonoKote
Propulsion	Engine	OS 60 FX
	Propeller	12x6
Control	Flight control servos	Rudder, elevator, aileron, and throttle
Avionics and Sensors	Computer system	Tri-M MZ104
	DGPS	Royaltek RB2100
	Autopilot	BTA (gyro and barometer)
	Communication	Stamptronics Wireless Modems
	Camera	SuperCircuits CCD Camera

4.1. SOFTWARE SYSTEM

The airplane runs a small embedded Linux operating system. Since we are using the BTA Autopilot for low level stabilization of the airplane the control loop can be greatly simplified. The main control loop is heading control, it has a target co-ordinate and current co-ordinate information from the GPS. It compares these two and generates a heading command for the BTA. When a position is reached it moves onto the next point. The final point is always looped so that it will return to that point. In the future the airplane maybe updated with a vision system, but currently the main goal is to accomplish autonomous flight.

5. BASE STATION

The base station is responsible for collecting telemetry data from the aerial vehicles and displaying the returned pictures.

6. VISION SYSTEM

The vision and object identification software is one of the most important software components in the overall system. The success of the entire mission depends on the vision software to identify the target building. The overall mission strategy is to supply the vision software with a continuous and somewhat random selection of images which, as time goes on, will provide coverage of, and then redundant coverage of the target area. As information distilled from these images becomes available, the vehicle can be instructed to look for an open opening in the target building.

The image capture will first roughly cover the arena uniformly with some overlap. Each image capture will be accompanied with the location of its four corners which is computed from capture time, the helicopter's trajectory in three dimensions, the helicopter's orientation, and the effective focal length of the vision system. It should be noted that since the location of the four corners is known, the absolute size of image features can be estimated.

The vision system provides the vehicle with information on location and identity of various target objects.

In general the images are dealt with as follows. First an image is checked using simple methods to attempt to exclude it as containing targets in order to reduce the amount of computation. If, on the other hand, the image exhibits enough variation, the image is then segmented for further processing. The segmented image is then analyzed to determine if it is likely to contain an object of interest.

To recognize the target pattern and identify the target building, the regions found by the segmenter are tested for target candidates based on colour (dark), shape, and size Possible targets are examined for interior labels, again based on colour (white), shape, size, and orientation. If a good candidate is found, it is then tested against the known shapes. Testing can then proceed by template matching.

7. CONCLUSION

Our system for this competition is an exercise in simplification. For us to attempt the rest of the mission, our vehicles must fly autonomously before anything else. We started out with the airplane because of its simplicity and past experience. We are looking at the helicopter for the future, because the ability to hover gives us advantages in looking for the target building and launching a small land vehicle inside the building.

We wish to thank all our sponsors: NovAtel, Lineo, BC Advanced Systems Institute, Systron Donner, Aaeon, Creo, Tri-M Systems, Silent Witness, Tokin, Broadcom, Simon Fraser University and Engineering Science, Applied Science and Centre for System Science at Simon Fraser University for making this project a possibility.