AUVSI Student UAS Competition

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Great Mills High School Engineering Club Team

Abstract

This journal paper describes the Great Mills High School Team's unmanned aerial system (UAS) for entry into the 2011 AUVSI Student UAS Competition.

The UAS is composed of two technical subsystems, one unmanned aerial vehicle (UAV) that autonomously takes flight and the ground control station (GCS) which interacts with the UAV's internal Micropilot autopilot and directs flight parameters.

Introduction

Two years ago, the Great Mills Unmanned Aerial System (UAS) team acquired resources, comprising a plane and an integrated MicroPilot autopilot avionics package that enabled them to compete at Patuxent River Naval Air Base in the 2009 Auvsi competition. This year's project is a continuation of the pioneer project the Great Mills UAS team set in motion in the previous years. The team purchased and built a kit plane as well as purchased an ARF of the same model.

Mission

The general mission scenario dictates that a United States Marine Corp strike team needs intelligence on a defined area (Webster Field). This area contains hostile forces as well as civilians but also includes 'pop-up' targets, all of which need to be identified in order to allow the Marines to enact a successful air strike.

The mission is sectioned into three phases:

(1)Takeoff
(2) Waypoint Navigation
(3) Landing

(1) The first phase consists of a difference between autonomous and manual takeoff, with additional points given to the former. UAVs can take to the air in either manner while still being able to complete the second phase.

(2) The second phase is split into three tasks. The first task requires pre-planned autonomous navigation to GPS coordinates announced the day of the competition, described in latitude, longitude, and altitude components. The second task consists of adjusting waypoint navigation in order to avoid in-flight hazards. The third task involves the correct identification and location of designated targets ranging in colors (Red, Orange, Yellow, Green, Blue, Black, & White).

(3) Autonomous landing will also score bonus points, but is not a mandatory function.

Mechanical Design

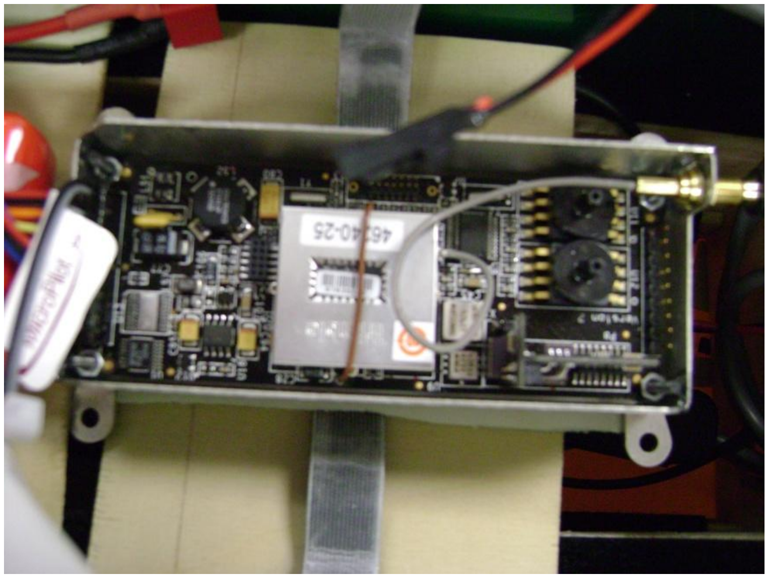
The aircraft is a Senior Telemaster aircraft that has been modified to hold an autopilot and camera in order to complete the tasks given to us. The plane has a wingspan of 95 in. and the fuselage is 60 in. The aircraft weighs 12.9 pounds without fuel. The UAV is propelled by a four stroke 120 Surpass III engine which uses a methyl, alcohol, and nitro-methane mix fuel. The propeller is a 14x6 which is manufactured by Master Airscrew.

This aircraft was built from a kit so the construction of the body of the aircraft was mainly completed last year. This is a "from the ground up" plane that we have completely constructed ourselves. We first made the plane able to fly, and then we created a platform system to hold everything that is needed for flight, autonomous flight, and our camera system. The airfoil can be repaired and exterior components are easily maintained with extra pieces of the airplane's skin material and an iron.

The fuel tank is located directly behind the engine. In the first cabin from the bottom there is the transmitter, then the battery and the autopilot. In the next compartment there is the camera followed by the Range Video On Screen Display. Everything is arranged on a series of shelves attached to the sides of the fuselage by Velcro for easy access to all of the parts for any emergency maintenance but still holds them in the plane while in flight and transit.

The GPS antenna is then located on the exterior of the plane's top side directly behind the engine on top of the panel covering the fuel tank. The Radio Control (R/C) antennae is threaded and attached to the top of the aircraft. The back half of the fuselage following the camera equipment is scarce and only has two servos to control the tail flaps, this is to maintain a stable center of gravity.

Electrical Design/Autopilot



The avionics installed in the fuselage include a MicroPilot 1028_g autopilot, manufactured and sold by MicroPilot. The autopilot system is comprised of a microprocessor, GPS, 3-axis gyro, and air data sensors. The autopilot is designed to allow flight control in either manual mode (Pilot in Control (PiC)) or autonomous mode (Computer in Control (CiC)). PiC mode bypasses all autopilot functions and allows direct (R/C) control of the servos via a Fail-Safe Switch. In PiC mode the Senior Telemaster must be flown following Visual Flight Regulations (VFR). In CiC mode the autopilot provides control. The autopilot has 12 feedback control loops: ailerons from roll, elevator from pitch, rudder from Y accelerometer, rudder from heading, throttle from speed, throttle from altitude, pitch from altitude, pitch from AGL (enabled during landing and controls the flare), pitch from airspeed, roll from heading, heading from cross-track error, pitch from descent, and roll from radius.

<u>MP 1028_g Core</u>

The MP 1028_g Core contains the microprocessor of the autopilot and acts as the control mastermind of the UAV. It directs information, processes actions, and records results, sending them down to the GCS through the data link. In addition, the core houses gyros and accelerometers, air pressure monitors, and other vital air data sensory feedback.

<u>Servo Expansion Board</u>

The Servo Board connects the autopilot to the avionics control servos including the rudder, throttle, elevators, and ailerons. These are input into their respective ‘S’ slots via the standard three pin connectors

GPS Antenna

The GPS Antenna connects the autopilot directly to triangulate current position, velocity, and altitude.

Compass

The Compass gives vital information like heading, wind speed, and wind direction, allowing for a dead-reckoning capability in the event of a data-link/satellite-link catastrophic failure.

R/C Receiver

The R/C Receiver is the standard PiC remote-control connection link that came standard with the Senior Telemaster. The receiver is connected to the failsafe in order to allow an in-flight PiC/CiC switch in the event of that the autopilot becomes incapable of maintaining flight.

Radio Modem

The radio modem is the medium through which connection is achieved between the GCS and the autopilot.

Fail-Safe

The fail-safe for our system is built into the R/C controller. The safety pilot will use the dead-man stick to switch between PiC and CiC. When the autopilot is in control an R/C link must still be established. If the R/C link is lost while in CiC mode, the plane will terminate itself. If the autopilot fails, the safety pilot will take over in PiC mode. In the event of both autopilot and R/C link failing, the plane will receive a signal to terminate itself.

Software

Horizon 3.4 Interface:

Horizon is the sister software of the 1028g MicroPilot autopilot. The program is used on a laptop. The Horizon software provides situational awareness of the UAV's environment, including altitude, speed, wind speed, attitude, heading, and GPS location. The GCS also monitors autopilot, C2 link, and power.

From the GCS, operators are able to communicate with the autopilot of the UAV so that it will autonomously take off, land, and follow previously determined flight patterns. Flight patterns are recorded by entering a series of waypoints into the GCS, allowing for the control of altitude and GPS location of the vehicle. Flights can be simulated well before actual flight to show how the UAV would respond in normal flight conditions to the flight pattern.

Prior to take-off, internal pilots map and plan out a waypoint file that depicts a GPS point-to-point itinerary for the UAV as it is airborne. Generally, these waypoint flight paths are generated by manually adding waypoints and dragging them to their desired locations. Waypoint maps can be created mathematically, but the point-and-click method allows for quick and easy integration, understanding, and versatility. During the AUVSI competition, the internal pilots will attempt to create a waypoint map that will produce a video clip which will cover a maximum amount of the operational area.

One of several key concerns of internal pilots is the physical orientation of the plane. The camera is located within the underbelly of the craft and points directly downward, meaning that any turning, sharp inclines, and sharp declines can drastically change the amount of coverage observed, as well as the precise clarity of the viewing camera. A straight and level flight is ideal, and so, flight waypoint maps with long, linear sections are best.

Another concern is the spacing between parallel flight paths, as well as the clearance of the flight path with the defined safe operational boundaries. Internal pilots use the 'ruler tool' to measure consistent distance between points along the flight path.

Internal pilots also have to keep in mind the available flight time and fuel as they construct their waypoint map. Some maps can be comprehensive, but far too lengthy, while other maps may be less inclusive, but fall within the time frame. Internal pilots must find that delicate balance in order to create the best-fit scenario.

The GCS screen can show a map of the flight area when it is downloaded to the GCS. The available map is extremely helpful in aiding the operator in better understanding the environment of the UAV, in a simulation or during flight, so that operators can make flight adjustments as necessary. Simulated flight aids are helpful in predicting any possible problems such as a breach of boundary or not covering target flight path.

Adjustments during flight can be made by GCS operators to correct any previously made errors or unexpected occurrences. The operators make use of aircraft readings such as altitude, attitude, airspeed, and heading to recognize when flight adjustments are necessary. Then, the GCS operators use screen features to make adjustments.

They make changes to altitude and airspeed through selecting up or down arrows on the corresponding screen features. The operators also make changes to GPS location through clicking and dragging waypoints on the map, thus changing the flight pattern.

Payload

Camera

The video camera that we have selected is the JVC Everio video camera. This camera's resolution adequately meets our needs to stream live video footage from the UAV to our ground station and allows the team to observe the live video stream. The resolution on the Everio is 840x624, which allows the team at ground station to comfortably view the footage and easily spot the required targets for the mission. The Everio has the ability to zoom up to 40 times without hindering the video resolution, and is a useful feature during flight. The camera is the optimal choice for this operation because it has a composite video output jack which is compatible with our wireless video transmitter (RVOSD system). It also has a durable battery which lasts approximately 2 hours, long enough to last multiple takeoffs and landings. The camera's size is also important to the mission because it is the appropriate size to fit inside the plane's inner fuselage. Its dimensions are 2.1'' for width, 2.7'' for height, and 4.5'' for its depth. It weighs in at about 11 oz.. It is light enough to not impair the plane's flight, yet it is built out of sturdy material which offers a strong enough case to protect the important components. Accompanied with the camera is an 8 GB memory card which will provide the camera with enough space to record up to 3 hours of high quality video on board. This provides a redundancy should there be a problem with the recording software on our computer.

Video Link

The wireless transmitter on board the plane is a 2.4 GHz RangeVideo transceiver, accompanied with the RangeVideo RVOSD (RangeVideo on screen display). The RVOSD provides useful information on screen such as altitude, GPS coordinates, wind speed, and temperature over the original video feed. At ground control, there is a paired 2.4 GHz receiver that will collect the video being transmitted by the plane, and the feed will be routed simultaneously into a computer via a PCMCIA video capture card as well as a television at ground station. This setup will allow our team to effectively view live footage as well as rewind to further analyze the footage to locate targets.

Strategy Rationale

In the first phase teams are to successfully take off, which can be done autonomously for points or can be done manually. With our teams experience with autonomous flight we have chosen to instead take off manually and once in the air switch over to the autopilot.

The first task of the second phase should be relatively simple to complete on the assumption that the autopilot is correctly calibrated, as the Horizon software inherently gives the ability to design waypoint maps and adjust the course in-flight.

The second task of the second phase has been eliminated from our task list due to our amateur skill level with the autopilot. Instead of deviating from the given coordinates to avoid the in-flight hazard, we have decided to fly the given coordinates as is.

The third task is to locate targets on ground and give their specific location. This task will be executed using our JVC Everio video camera pointed downward and our 2.4 GHz video transceiver. Our video feed will be sent to our RVOSD where we will be able to record our feed so we can review our footage and locate targets.

In the third phase you are to land the UAV successfully. This can either be done autonomously or manually, and like the take off we have decided to manually land the plane.

Testing and Evaluation

First Flight Test: Helwig Field

- -testing basic flight performance in takeoffs, an oval flight pattern, and recovery
- -successful flight
- -improved flight checklist and procedures

Second Flight Test: Helwig Field

- -ballast flight test with camera onboard recording
- -successful flight
- -pump screws needed to be replaced for tighter ones
- -fuel leakage discovered
- -camera shut off early due to vibration of the hard drive, thus we moved to an SD card

Third Flight Test: Helwig Field

- -testing wireless transmission system while in flight and retrieving feed to GCS
- -successful flight
- -damage to landing gear (rear wheel)
- -determined proper zoom setting
- -decided video capture card was needed

Fourth Flight Test: Helwig Field

- -testing aircraft for autopilot communications (not connected to servos)
- -failed flight
- -transmitter battery failed to hold charge
- -fuel leakage

Fifth Flight Test: Helwig Field

- -testing aircraft for autopilot communications (not connected to servos)
- -successful flight
- -software issues with autopilot
- -orientation of camera corrected for optimum viewing

Sixth Flight Test: Helwig Field

- -testing autopilot communication (not connected to servos), video capture card, and stall flight
- -successful flight
- -pitot tube misreadings

GMHS UAS Team

-Flight Test Coordinator (FTC)

- The FTC runs every flight, communicating between the safety pilot (SP), autopilot operator (AO), and payload operator (PO)

-Aircraft Handlers

- These are the mechanical engineers of the group. They oversee, operate, and maintain the airframe, autopilot, electronics board, servos, engine, and overall well-being of the UAS

-Autopilot Operators (AO)

- AO group operates the autopilot from the ground control station (GCS). They plan and direct waypoint navigation while observing real-time instrument feedback.

-Payload Operators (PO)

- PO group is in charge of running the RVOSD and analyzing footage from the GCS.

-Judge Coordinator (JC)

- The JC is a person available in the GCS to answer any questions judges have during flight when we are operating our systems.

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