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SUAS 2009 Competition Journal

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TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Recently conducted research shows that remote controlled aircraft such as airplanes and helicopters are often utilized for surveillance purposes. The military often utilize resources such as UAVs (Unmanned Aerial Vehicles) to conduct reconnaissance, surveillance and data acquisition missions due to the versatility and easy deployment of this type of equipment.

The desired design will incorporate features such as an integrated camera system, and radio modems for real time data collection and transmission. The platform is to be modular in nature, allowing for the complete assembly to be easily transported and be flight ready in less than forty five minutes. It will incorporate features and safety mechanisms that are in compliance with the Association of Model Aircraft (AMA) as wells as the Association of Unmanned Vehicles Systems International (AUVSI).

MOTIVATION

The proposed aircraft is intended for entry in the 7th Annual Student Unmanned Aerial Systems (UAS) competition which is brought forth by the association of unmanned vehicles systems international. The competition aims to stimulate and promote interest in UAV innovative technology and above all to encourage careers in the field. The competition challenges the students to design, fabricate, and demonstrate a system capable of completing a specific and independent aerial operation. Given these parameters the objectives of this project are being focused on developing a UAV platform that will able to integrate all the necessary features to participate in this completion and provide the endurance to successfully complete the given task.

At the 2008 HENAAC conference in Huston, Texas, many private companies and as well as government and federal agencies have clear interest in UAV technology. Companies such as Lockheed Martin, Boeing, Northrop Grumman, General Dynamics and Raytheon showed great interest in projects like this, where engineering students develop UAS platforms for practical applications.

At a personal level, the students involved in this assignment were driven to explore all aspects of aircraft design that range from conceptual design to building techniques and testing approach. In this way, the project can be successful in providing the students with firsthand experience on development, construction and component integration of an aircraft model that are critical for any UAV company to operate successfully.

AIRFRAME DESIGN

The initial aim of the team was to build an airframe capable of VSTOL flight. This would allow the aircraft to be launched and landed in almost any terrain condition. Also, if the hover abilities of the airplane where stable, this feature could be use to hover over an target to be motored.

The development of such airframe was inspired by the Sikorski Cypher I and II, and the Vertigo by Tom Hunt. Our vision of an airframe capable to meet such flight characteristics was developed in two stages. First was the study of a simple airframe modified to fit a coaxial motor for VTOL and a second rear motor for forward flight.

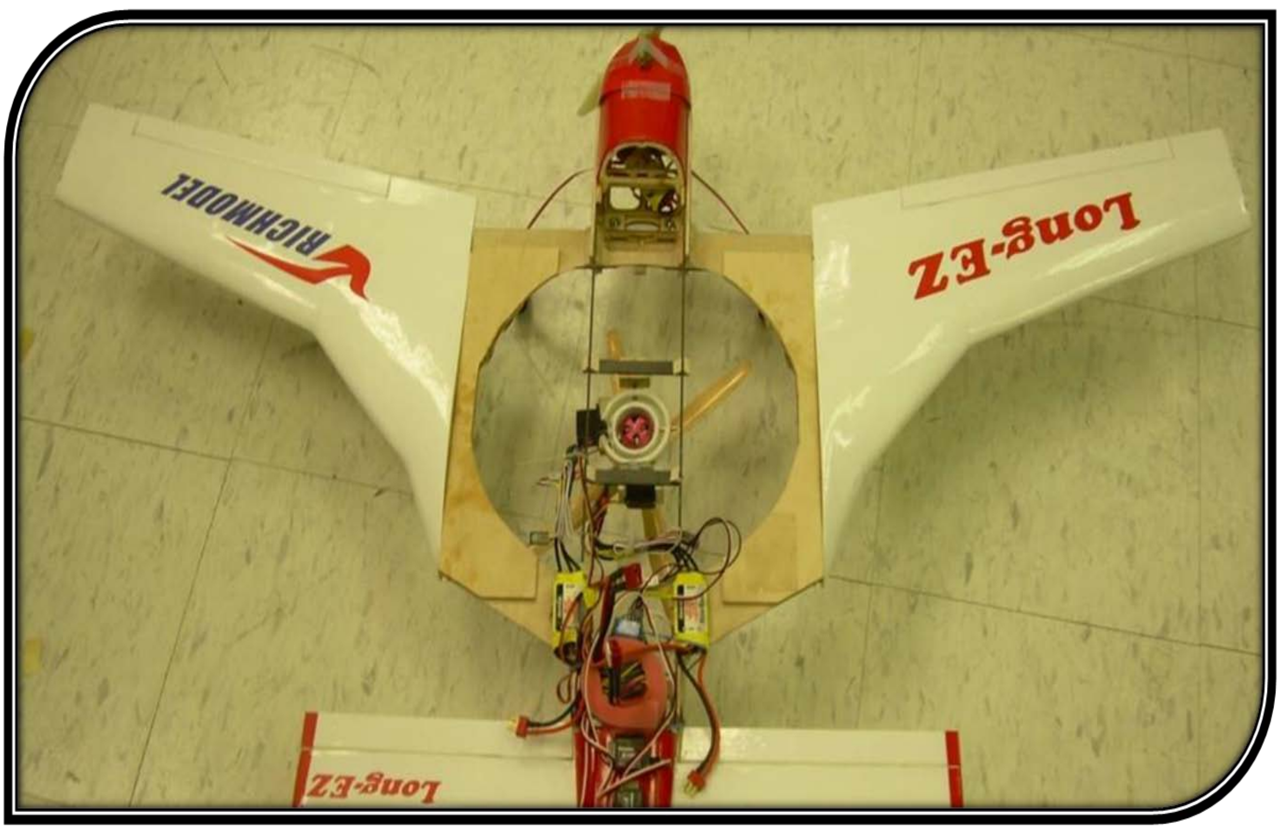


Figure 1: Long EZ, modified for VTOL capabilities

Figure 2: Long EZ, Hover testing

The results from the first airframe where encouraging enough to send the team to build a second prototype. This time building the airframe with some guidelines from the Vertigo and incorporating features that would allow the aircraft to be fully modular.

For the construction of the second prototype a Solidworks model was created. This model allowed us to see potential problems in the construction of the real model. Many tools where constructed in order to cut the foam cores which served as the main boby. These cores where sheeted with balsa to strengthen and add rigidity.

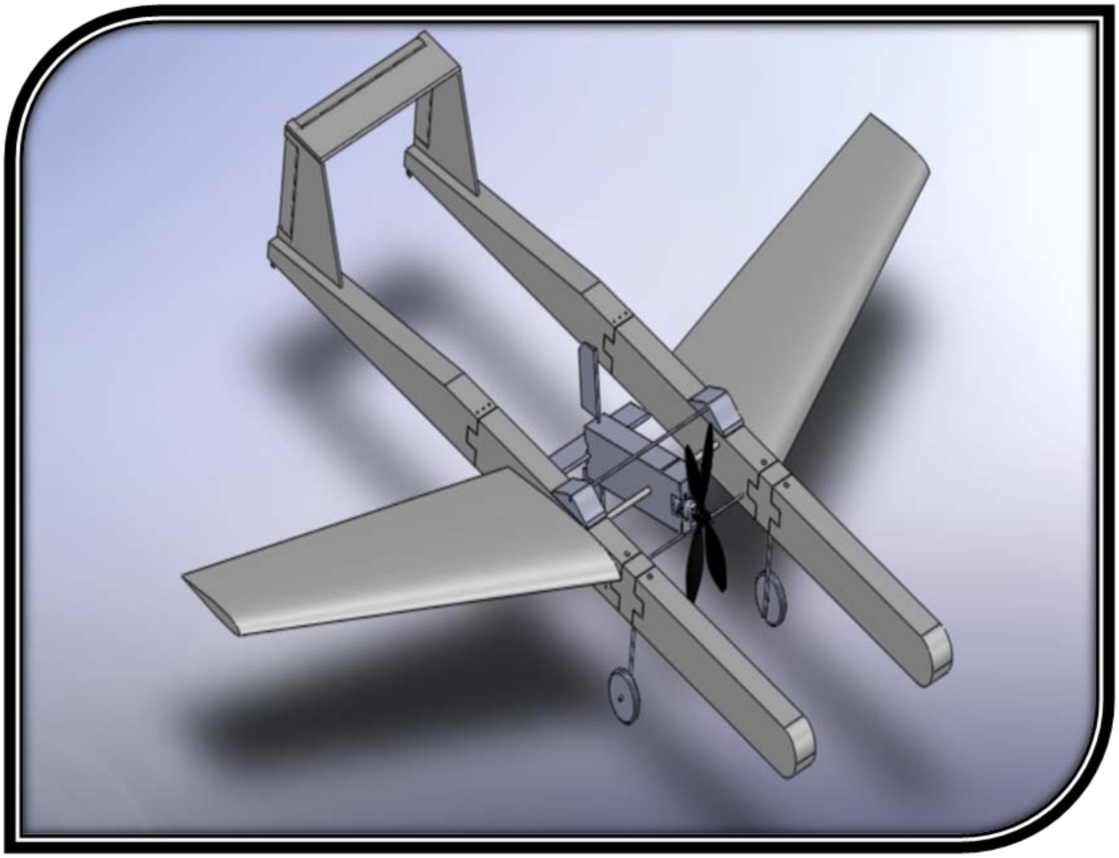


Figure 3: Second prototype Solidworks model.

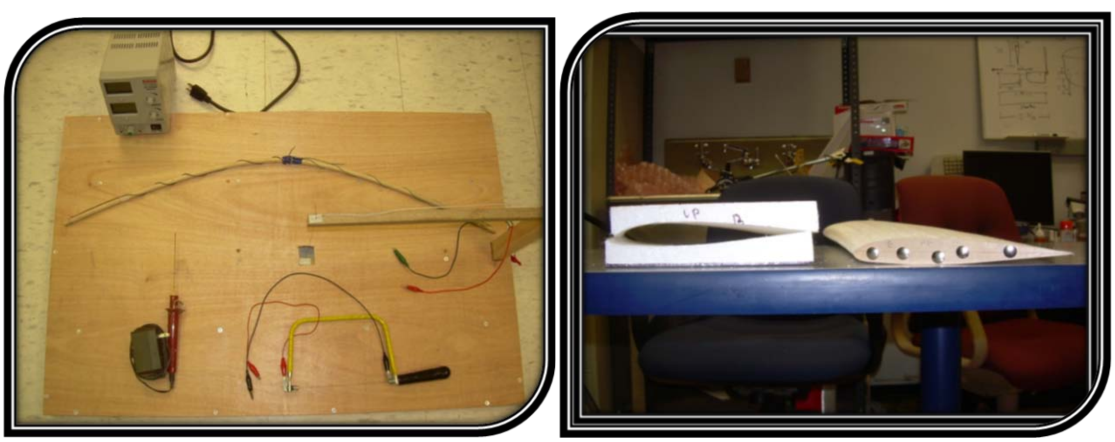


Figure 4: Foam cutters and wing panel section

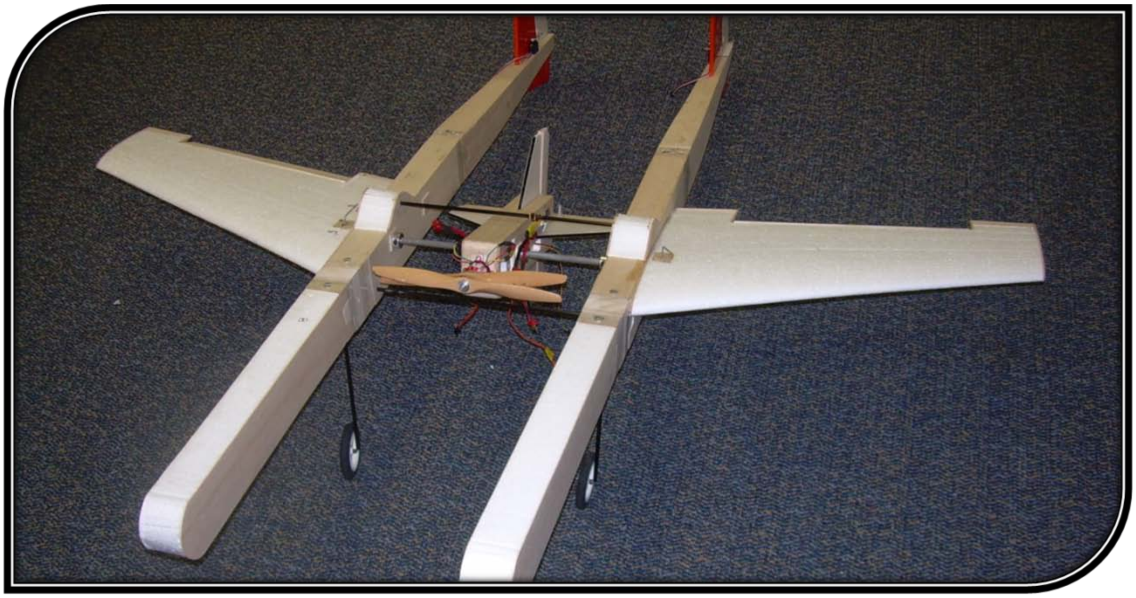


Figure 5: Final prototype before wood sheeting

Unfortunately for our team, during hover testing the aircraft was damaged beyond repair and the construction of a second model would required to many hours, so the project was dropped for this years event and an alternative airframe ARF Telemaster was chosen.

The final airframe selected is the Hobby-Lobby Telemaster, This 6' aircraft is capable of carrying great loads while maintaining stable flight and very predictable flight characteristics.

The main power system was chosen to be electric in order to minimize vibrations that would interfere with the camera system. The mission is intended to be flown in less than twenty minutes, however, the systems is fitted with two 4900mah 18.5V lithium polymer batteries which can fly for over 50 minutes at 60% throttle and 30 minutes at 75% throttle given the endurance needed for the competition. This also provides a safety margin in order to comeback to the home position in the event of an extended mission plan.

AUTOPILOT NAVIGATION

In order to comply with the autonomous section of the competition an off the shelf autopilot system was chosen. Attopilot V1.8 was chosen for its ability to hold a flight pattern, real time telemetry, ability to log over 50 parameters, re-task ability of flight plan, overall ease of use, fantastic support and the lowest price available. Attopilot was also sponsored to the team by Dean Goedde at a discounted price.

Figure 6: Attopilot V1.8

Navigation stability

The system utilizes thermopile sensors in order to control stability in 3 axis. Attopilot is a self contained unit that includes pressure sensor, pitot tube for static and dynamic air speed, and GPS chip for navigation. It also includes a ground command station (GCS) that allows control of the system via a laptop. The GCS can connect to the autopilot and dynamically display the aircraft position, velocity, heading, heading error, altitude and power consumed using the virtual a virtual cockpit. It can also overlay a graph in a map using Google Earth. A gyro unit has been added in order to aid the landings in manual mode.

Safety

In order to have a robust platform safety of the system most be consider. The system counts with several safety mechanisms both in flight as well as on the ground in order to prevent or minimize accidental damage.

Ground safety includes:

1. Visual inspection of electric wires, motor screws, battery condition and airframe integrity before every flight
2. Propeller tips painted white for visual reference
3. independent cut-off switches for main power, camera system and communication modems
4. range check of radio gear prior to flight
5. Lithium polymer batteries are charged in safety pouches and are bright yellow for easy identification.

Flight safety:

1. ability to switch between manual mode and autonomous mode
2. ground station link loss for more than 30 seconds return to home
3. flight distance limit, if exceeded the aircraft returns home
4. Battery voltage level will not drop below needed voltage to return home.
5. if satellite link lost hold circle pattern, after 3 minutes spiral descend
6. lost signal more than 3 minutes, spiral descend
7. receiver failsafe enable if autopilot fail, spiral descend
8. assisted IR landing for manual mode for inexperienced pilots

VIDEO INTEGRATION

The video system is comprised of a VGA camera capable of 520 lines of resolution in the NTSC format. This video system was chosen for its ability to be easily integrated with video transmission system, low cost and video steam capability. This camera allows a video stream to be sent to the ground station for scanning. Once a possible target is detected one of the frames is selected for analysis. This frame is then analyzed using the following method.

System Architecture

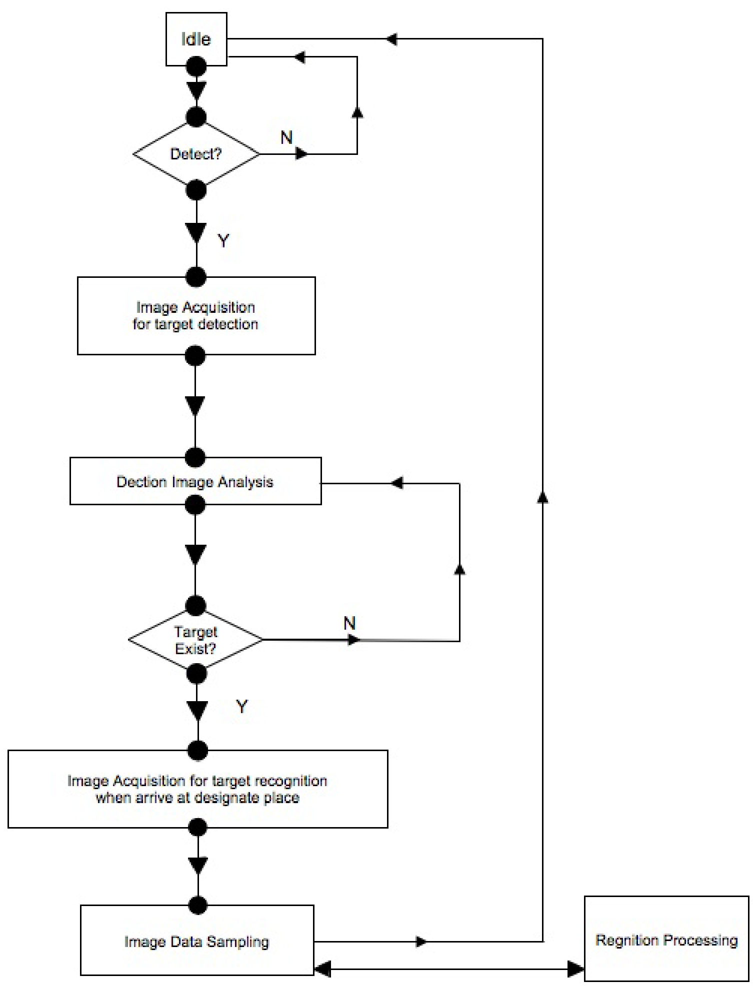


Figure 7: System Architecture Description

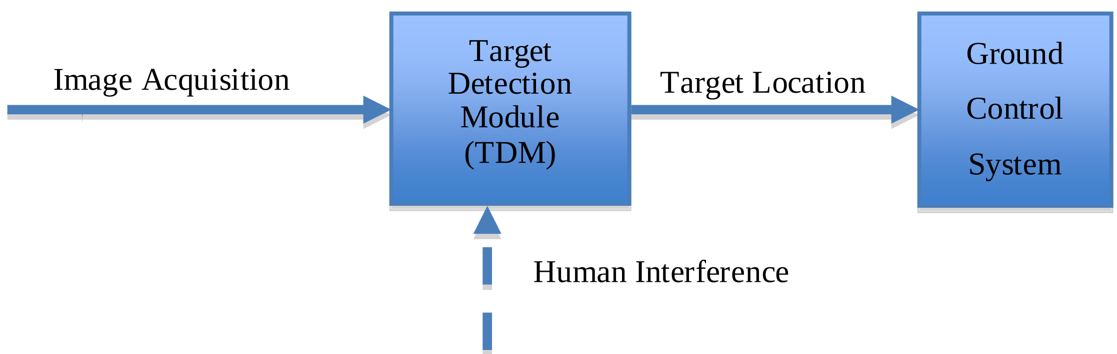
The ground control system includes:

1. Target detection module
2. Target recognition module
3. Decision making module

The function and architecture of each module is as below:

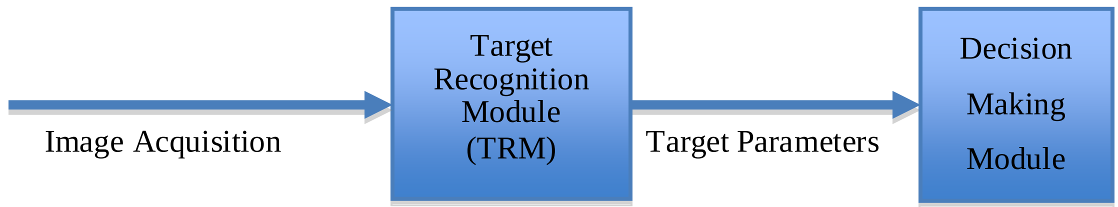
a. Target Detection Module

Target Detection module receives image data, processes the image without human interference and gives a decision to aerial vehicle with information of target location. The vehicle should get the target location information and go to that place with any further recognition process elaborately. The detection module will apply edge detection in R, G and B plane separately and combine the result together to get all the objects in that image. We have to set a size ratio threshold, which depends on the range of object size, height of the plane and the focal length of the camera we used, to distinguish the real objects we want from other ones. For the qualified objects, find the central point of the object, and the real GPS position will be calculated through the current position of the plane and send back to ground control system for further processing.



b. Target Recognition Module

When aerial vehicle has arrived at some designated place, Target Recognition Module will sample the images and do the image recognition.



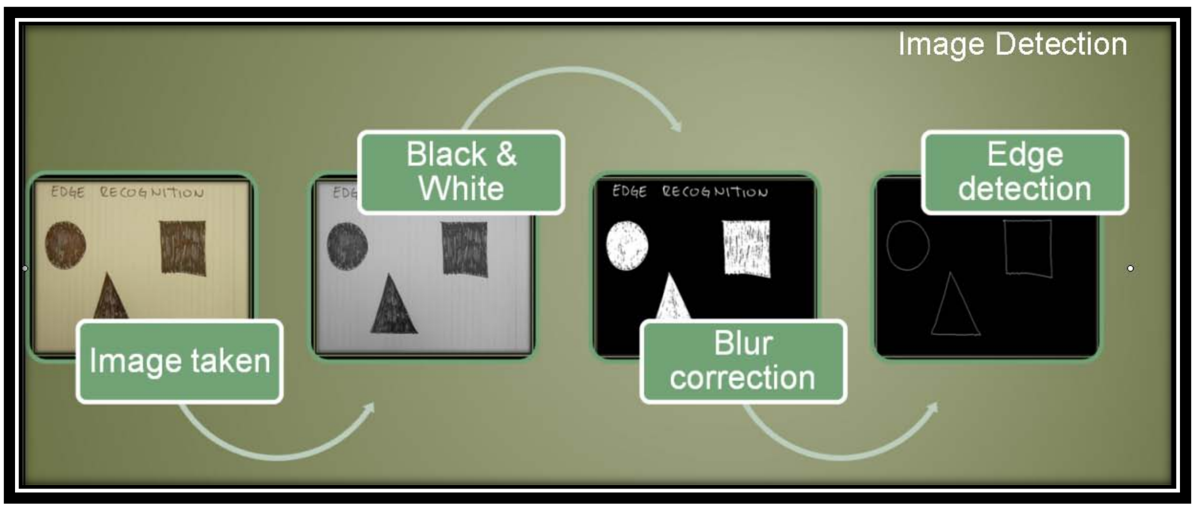


Figure 8: Edge detection

1) Noise deduction. The first step for the image processing is to remove the noise. Hybrid Median filter is used in our case. It is a three-step ranking operation [15]. For a 3x3-pixel neighborhood, pixels are ranked in two groups, one in the 45 degree neighbors forming an 'x' and another in the 90 degree neighbors forming an '+', and the median value of the set is determined as the new pixel value. This method can preserve the lines and corners which are removed from conventional median algorithm.

2) Shape segmentation. For the geometric shape segmentation, different methods for shape segmentation are considered. First, we need to do the edge detection. It can be done on gray scale image or original color image. The method implemented first is to convert the color image into a gray scale one, and then apply the edge detection. However, after a synthetic testing image, this method becomes unstable. For some cases, although the contrast between the background and subject is significant, after converting to gray scale, the difference between them is hard to detect. Better result could be obtained through edge detection applied on RGB plane separately in the original image. In our case, it shows both the edge of the shape and the character inside. Then boundary detection is used based on the threshold. The threshold is determined by the size restriction on the shape objects.

3) Shape Recognition. The signature algorithm is used for shape recognition. A signature is a 1-D functional representation of a boundary. The one we used is to plot the distance from an interior point to the boundary as a function of angle. It is a simple way to recognize the shape. For example, if the shape is a triangle, the figure of the signature will have three local maximum and if the shape is a rectangle, the signature will have four local maximum. Moreover, it can also distinguish the cross from polygon with 8 sides.

4) Alphanumeric Recognition. Through the boundary of the shape, the points inside the shape are located. The alphanumeric inside the shape can be separated easily through the contrast difference. The most common method is utilized some training methods, neural network or support vector machine. However, most of those character recognition applications have no discussion with the rotation problem. In our case, the rotation of the character is required to be considered. Then the training process for the two methods mentioned above is more complicated than PCA with nearest neighborhood algorithm. Hence in this application, PCA is used as the dimension reduced method and the recognition is based on the nearest neighborhood classifier. The training data is composed of the characters with rotation at every 10 degrees. And the preprocessing step for the characters is to normalize it into a specific size of 20x20. Moreover, in the

character recognition step, the orientation of the character can be determined which can combine the image orientation to determine the object orientation. And a color table is generated with 25 colors, which is used to determine the color of the shape and the color of the character.

c. Decision Making Module

Decision making module is to a display and report module to give the final result for human to read.

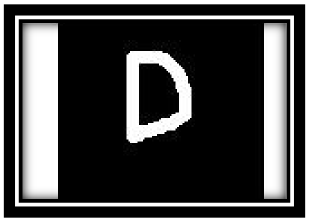


Figure 9: Original image only contains the black background and white character

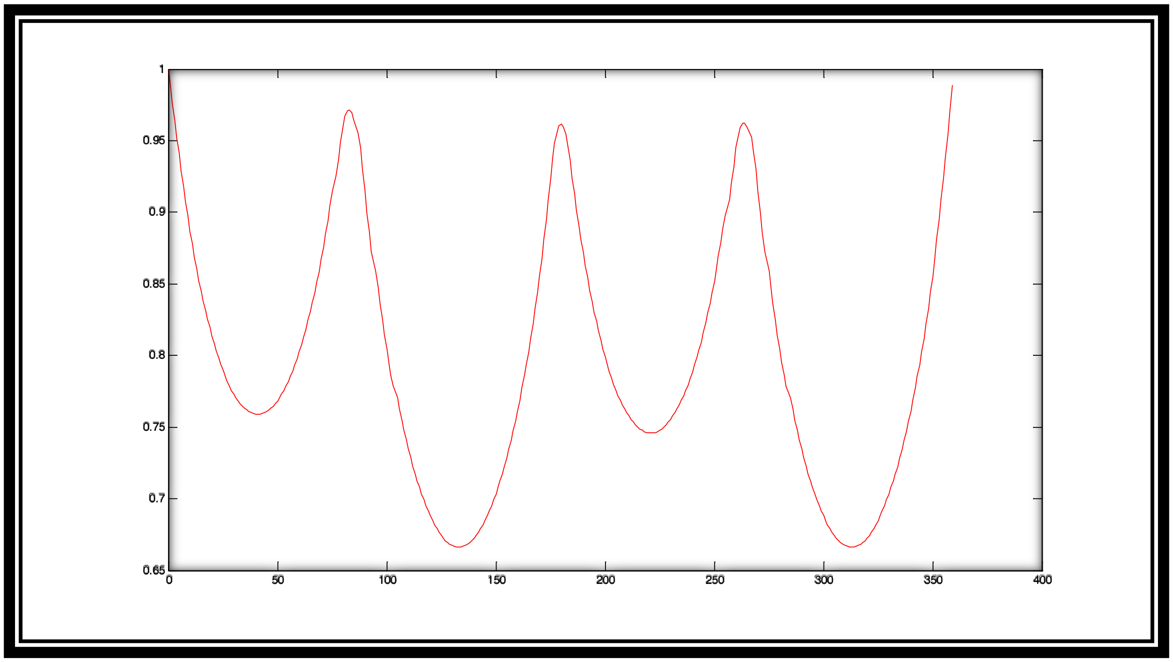


Figure 10: Signature of the geometric shape

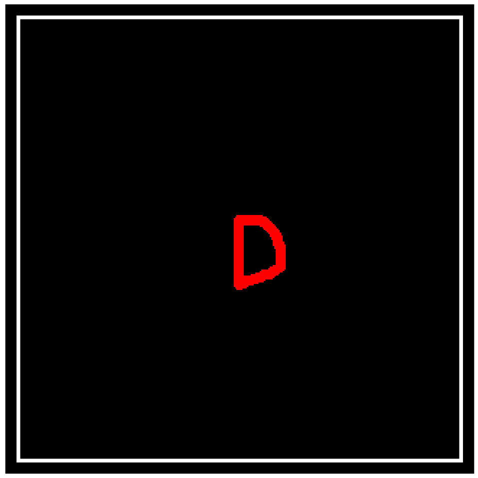


Figure 11: Detection of the character

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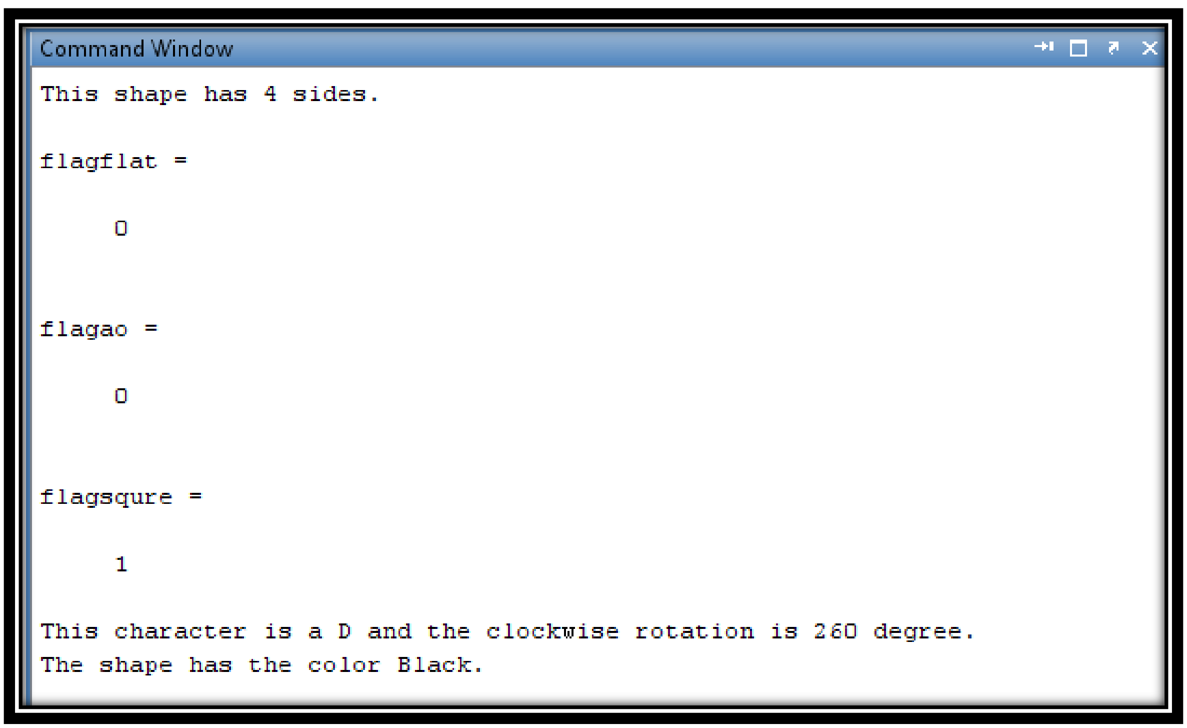

Figure 12: Other information in the command window

TESTING AND SYSTEM EVALUATION

The testing and improvement of the airframe and its components it is an ongoing effort. Thus far we have been successful in achieving autonomous flight which includes real-time telemetry and video feedback. Thought out the flight tests of the system it has been noticed great satiability and flight endurance which exceeds the 45 minutes limit set by the competition rules. Over 20 autonomous flights have been conducted and the transition between manual and autonomous modes have been successful with 100% reliability.

CONCLUSION

The creation of an UAV platform capable of autonomous flight and target detection was the aim of this project. Team Aguila Arpia was able to test several airframe designs which will provide a base for VSTOL capable aircraft for future competitions.
Using off the self components such as the camera system, autopilot navigation and an ARF aircraft allow the team to quickly and cost effectively build a system capable to meet the requirements set forth the UAS competition.

ACKNOWLEDGEMENTS

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