

Technical Paper for the International Aerial Robotics Competition

Paul Oppenheimer

Tim Fenwick

Sean Angermuller

Abstract

NCSU is competing in the 2001 International Aerial Robotics Competition. NC State's Aerial Robotics Team has developed a Twin Rotor autonomous helicopter designed to enter a building after flying a distance of 3 kilometers. This paper outlines the design of the entire system.

Table of Contents

- 1.0 Introduction
 - 1.1 Mission Requirements
 - 1.2 Design Overview
 - 1.3 Proposed Budget
 - 1.31 Expenses
 - 1.32 Sources of Money
 - 1.4 Organization of Team

- 2.0 Preliminary Design
 - 2.1 Vehicle Design
 - 2.2 Navigation Design
 - 2.3 Communications
 - 2.4 Controlling Hardware
 - 2.5 Electronic Schematic

- 5.0 Conclusion of Project
- References

1.0 Introduction

1.1 Mission Requirements

The purpose of this project was to compete in the International Aerial Robotics Competition (IARC). This year's competition involves designing and building an Unmanned Aerial Vehicle to take off and fly to a building of known GPS coordinates 3 km from the launch pad. The GPS coordinates will be at the intersection of several buildings. One of the buildings will have a symbol on it to distinguish it from the other buildings. Once the correct building has been identified, the aircraft has to locate an opening and fly inside. The building is guaranteed to have at least two openings of 1m X 1m. After entering the building, the aircraft has to relay pictures of every room in the building back to the launch pad. This is all done within 15 minutes and fully autonomous.

1.2 Design Overview

Early on it was decided that the vehicle was going to be some type of rotorcraft. A fixed wing aircraft would be difficult to fly inside the building, and a lighter than air vehicle would not be able to cover the distance in time. The thought of multiple aircraft was also considered, but this would require everything to be done twice. The main advantage of two aircraft is the second one could act as a repeater for the images from inside the building. As a team, it was decided that this alone did not outweigh the price of two autonomous systems.

Navigation was the next major requirement. Outside of the building, GPS was the first choice. Inertial measurement systems were considered, but the price for a system as accurate as we would need was higher than our budget could allow. Inside the building, a range finding sensor was selected to determine the distance from walls and obstructions.

The team went with commercial off the shelf (COTS) approach anytime we could. There is no reason to spend time on designing and building something if you could save time and have a better product by purchasing it. The limiting factor is this approach is being able to afford the products.

1.3 Financing

Estimated Expense	Amount
Ground Station	\$3,000
Flight Computer (FCS)	\$2,000
Sensors	\$6,000
Camera System/Communications	\$2,000
Radio Equipment	\$500
Batteries	\$500
Vehicle and Spare Parts	\$7,000
Total	\$21,000

Sponsorship	Amount
Touchstone Energy	\$1,500
Infinite Technology	\$5,000
Cisco	\$2,500
Heli-World (discounts)	\$500
Nortel	\$2,000
Student Government	\$3,000
Engineering Council	\$3,000
Northrop Grumman	\$2,500
Penske Truck Leasing	\$4,000
MAE Department	\$1,200
CSC Department	\$1,500
IBM	\$500
Total	\$27,200

1.4 Organization of Team

The team was broken into three smaller teams. They comprised of Electronics, Intelligence, and Vehicle teams. Each of these teams had sub teams that worked on specific areas. There was a weekly group meeting for the entire organization. The individual teams met regularly throughout the week.

2.0 Preliminary Design

2.1 Vehicle Design – The vehicle selected was Hirobo’s Vertol Twin Rotor Helicopter. This vehicle was selected based on its twin rotors and relatively

small disc area. The vehicle must fit through the 1m X 1m opening in the building. In any RC helicopter selected, the blades were going to have to be shortened. The Vertol only required two inches from each blade. Another advantage of the Vertol is a its large area to mount electronics. Several modifications were made to the helicopter. A larger engine was added to help provide additional lift. The cooling system of the helicopter had to be redesigned to cool the larger engine. Blades with a larger chord replaced the factory blades. To allow for large payloads under the aircraft, new landing gear was designed. Composite landing gear was made from layers of Kevlar, Silicate-Carbon Fiber, and RohaCell. A shroud was made to enclose the two discs. This was added for safety and allows the discs to be larger. If the shroud is stiff enough, the helicopter can bump the edge of the window going in without a crash. The clearance needed from the blade tips to window edge can then be reduced.

2.2 Navigtion

- 2.2.1 GPS – Navigation through the waypoints will be done using the Mighty Mouse II antenna with a Royal Tech receiver. These were chosen based on there low power and weight. They both also interface with the PC/104 described later.
- 2.2.2 Ultrasonic – Polaroid 6500 series ultrasonic sensors will be placed in an array around the shroud. The range for the ultrasonic sensors is up to 35'. The sensor is not accurate under 3'. The navigation will be transferred to them when the building is approached to detect the opening. They will also be used inside the building to map the walls. In the building, the sensors will be pinged based on which way the inertial measurements determine the aircraft is going. The sensors will primarily be mounted in the front of the aircraft, but one in the rear as well as up and down.
- 2.2.3 Infrared – The ultrasonic sensors are not accurate at small distances. Infrared range finding sensors are more ideal for this purpose. Two of these will be used to aid in the aircraft passing through the opening in the building.

2.3 Communications

We first had to decide what specifically our responsibilities were, and what priority each one had. The following list contains our responsibilities in order of priority:

- 1.) Provide a switch to transfer control from the remote handset to the on-board computer
- 2.) Provide a wireless emergency kill switch

- 3.) Establish a wireless digital link for diagnostics and testing
- 4.) Transmit a “yes” signal from the base location after a particular image has been recognized
- 5.) Transmit video data from the robot to the base location

For the transfer switch, we began analyzing the remote’s transmitted signal, which was a square wave. We designed and built a circuit that outputted a separate signal to be compared to the handset signal. This circuit was a mono stable operator built with a 555 Timer and will be placed on board the helicopter. The signal produced by this circuit was a square wave triggered by the rising edge of the remote’s square wave. We tailored the duty cycle of the 555 wave such that the cycle was longer than the remote’s “off” duty cycle and shorter than the remote’s “on” duty cycle. This allowed us to compare the two signals using logic gates and ultimately provide a 1 or 0 as an output for the whole system depending on whether the remote supplied an “on” or “off” duty cycle. Using this output we were able to control the source of the signal, which controlled the robot. Controlling this output was also implemented using logic gates. If output were 1, the source would be from the remote handset. If 0, the source would be from the on-board computer. The emergency kill switch will be activated by a signal from a solitary transmitter at the base location.

We have encountered several options concerning the digital link. One of the two we have considered uses a wireless Ethernet connection (by Linkmasters) and the other uses a wireless Serial connection (by Proxim). The specifications for the two are about the same. For the transceivers: 9V, 240mA, 9 ounces, 5” X 3” X 2”, 3 mile range, 100mW output power, 2.4 GHz operating frequency.

The “yes” signal will be transmitted after image processing and recognition indicates that the correct building to enter has been identified. This signal will more than likely be transmitted over the wireless digital link, but consideration of a separate device has also been discussed.

For the video transmission, we will use a micro B/W camera that are also equipped with infrared LEDS enabling them to see 10-12 feet in the dark. There is a transmission device from First Witness Video called the Ultra Link Video Transmitter that transmits up to fifteen miles. This product operates at 10-13V, 300mA, 2.4 GHz, 100mW output, and is 4” X 4” X 4” in a case, which may be removed.

2.4 Controlling Hardware

2.4.1 Overview - A combination of the Mitsubishi M16C and a PC/104 were selected as the controller and AI. The M16 is responsible for controlling the servos as well as input and output for all of the sensors. The PC/104 give the M16 commands and make the

decisions needed. The GPS and wireless link are connected to the PC/104 to provide it with information on making decisions.

2.4.2 PC/104 – The embedded PC chosen was the MZ-104 from Tri-M Systems. The board has 32 MB disk space as well as memory.

The processor on board is a 133 MHz and runs on less than 500mW of power.

2.4.3 Mitsubishi - To control the low-level aspects of the helicopter we decided to use an MCU board, Nekton Control Node (NCN). This gives us real-time control of all aspects of the control. The NCN has a Mitsubishi M16C624 and support components.

The specifications are:

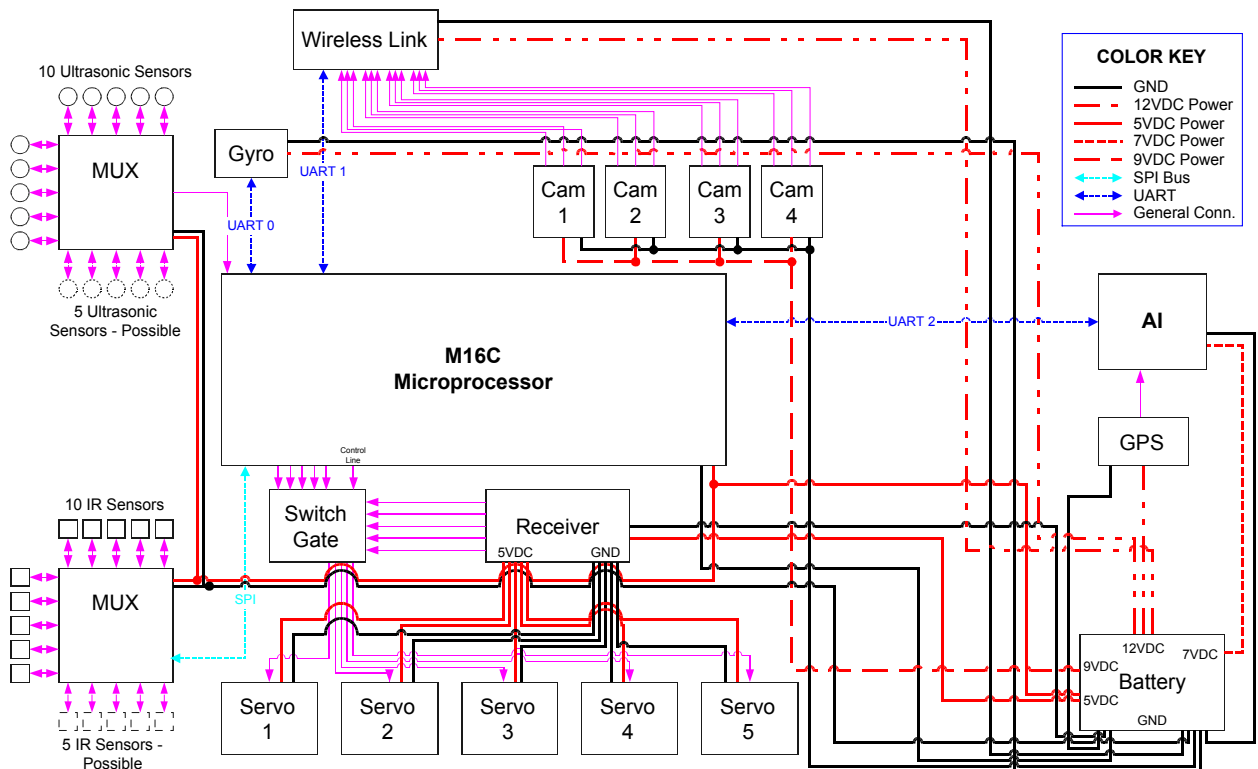
5 PWM output

6 UARTS, 4 with RS-232 output

33+ IO lines.

11 timers

2.5 Electronics Schematic



3.0 Conclusion –

We feel that our approach of using COTS components with reduced in house fabrication will be the winning method. This approach reduced the complexity from a design problem to an integration problem. During our first in competition the learning curve has been steep. We have all learned the importance of communication and teamwork in a project of this magnitude.