Formation Flying Blimps Project

AA449 Milestone Report 1

Beth Boardman

Linh Bui

Kyle Odland

Matthew Walker

Maggie Wintermute

Friday, April 9 2010

Introduction

The Distributed Space Systems Laboratory researches self-organizing robotic distributed systems with application to aerospace missions. Notable examples of aerospace networked systems that are currently being studied in the Lab are formation flying space vehicles or self-organizing satellite constellations. The scope of this technology is far from solely limited to space systems. One networked control system that is undergoing experimental verification is a collision avoidance algorithm, with obvious applications to many ground based systems.

To further develop and optimize these control systems, the Distributed Space Systems Lab is constructing a hardware testbed where these algorithms can be tested. This testbed will ultimately consist of a suite of small, autonomous robotic vehicles working in a cohesive network. At present, the Lab has two Lego Mindstorms Ground robots fully integrated with the tracking system and central computer. The fundamental goal of this project is to create two autonomously controlled, neutrally buoyant blimp vehicles to expand the capabilities of the Distributed Space Systems Laboratory testbed. A blimp model was chosen as the characteristically slower reaction time and inherent system stability make it an ideal vehicle for testing experimental control systems in an indoor facility.

Customer Profile

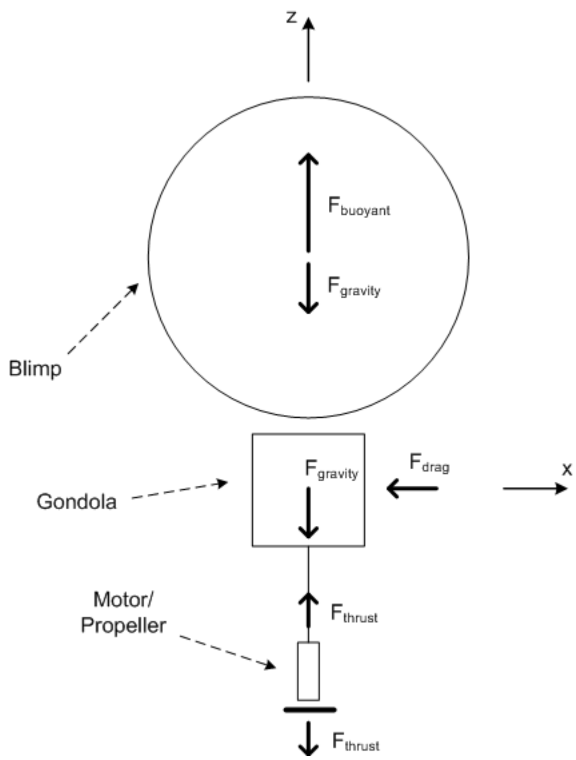
The principal investigator for the Distributed Space Systems Laboratory is Professor Mehran Mesbahi of the Aeronautics and Astronautics Department. Professor Mesbahi has defined the project goals, contributed the Lab as a workspace for component testing and construction, and is supplying the funding for this project.

Project Goals

1. Construct one working blimp vehicle that can complete simple waypoint tracking within the confines of the Distributed Space System Laboratory testbed facility, robust enough to be used for the future plans of the lab.
2. Construct a second working blimp vehicle that can complete simple waypoint tracking within the confines of the Distributed Space Systems Laboratory testbed facility, robust enough to be used for the future plans of the lab.
3. Derive and implement the control algorithms for a series of coordinated tasks for both operational blimp vehicles to conduct. This will start as a simple Lead/Follow scheme, and evolve to steadily more difficult tasks should project time allow.

Plant

The blimp will consist of a gondola suspended from a helium-filled balloon. The onboard components necessary for power and control will be included in the gondola structure. The blimp will be controlled in four degrees of freedom: translation in X, Y and Z, as well as rotation around the Z axis (yaw). Small electric motors will be mounted to the gondola structure, and will be used to actuate the system. A basic free body diagram of the system is given in Figure 1, both a side view and a top view.



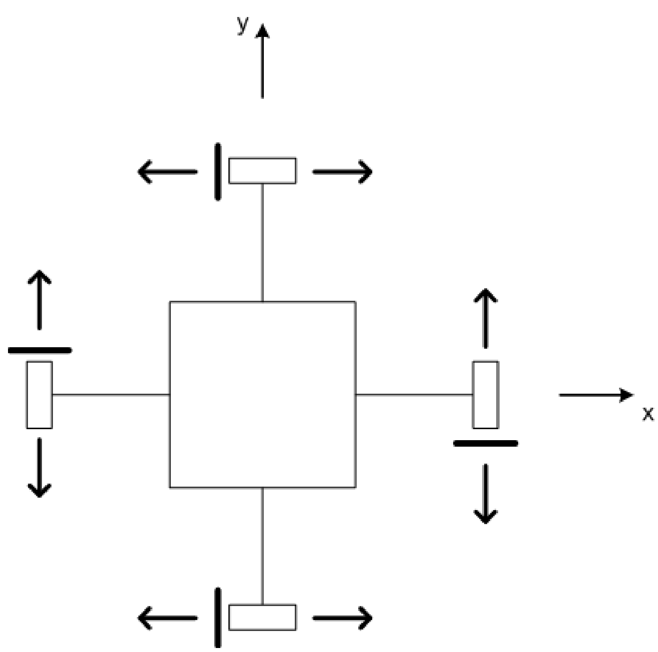


Figure 1: Free body diagram of initial blimp plant model

Sensors

The position of the blimp will be tracked by the Vicon camera system. An array of reflective dots is placed into a known arrangement on the vehicle. Using 6 cameras, the system can triangulate the <x,y,z> position of each dot. From this raw data, the position of the blimp's center of gravity and the heading of the vehicle can be determined.

Actuators

The actuators will consist of the motor/propeller combinations that are mounted to the gondola beneath the blimp. One of the primary requirements for these actuators is the ability to provide thrust in opposing directions. This will allow the vehicle to translate easily in all four degrees of freedom. The initial motor/propeller combination chosen for the Formation Flying Blimp project is the EDF-50 Ducted Fan Power system with an EDF-2020x3 rotor, operating with a 6.0V CN12-RLC motor. This configuration is detailed in Figure 2.

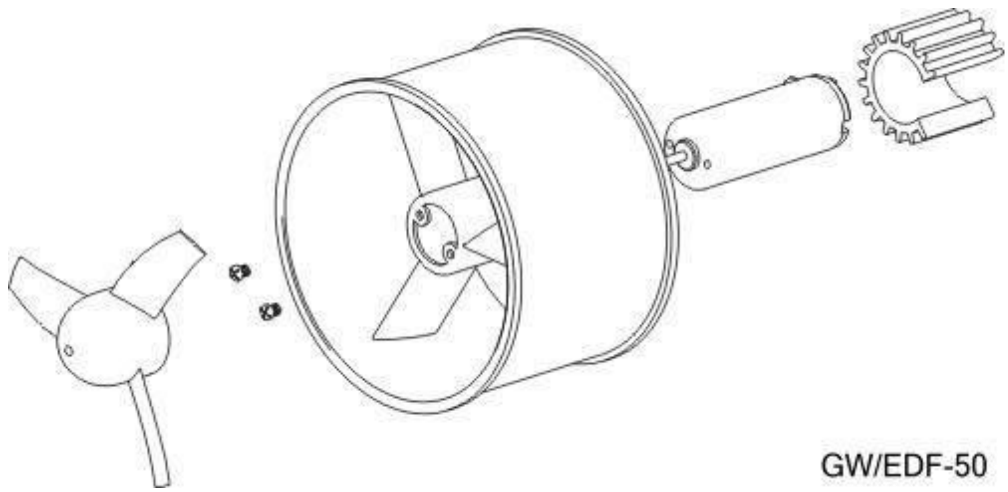


Figure 2: Initial motor/propeller configuration proposed. (Image courtesy of BP Hobbies)

Control Software Components

The specific components needed to execute the control law on board the each blimp has changed since the initial proposal for this project. It was the initial request of the Distributed Space System Laboratory to use hardware similar to that used on previous projects. The original plan was to use a Gumstix processor to compute the control law in conjunction with a Robostix processor to directly communicate with the actuators. Due to the lack of experience on the team with these devices, this platform has been substituted for an Atmel ATMega328P AVR microcontroller to be the primary unit to enact the control law and communicate with the actuators. This microcontroller will communicate with the Vicon system central computer wirelessly through an XBee Pro 900 RF module. A block diagram of the overall system architecture is included in Figure 3.

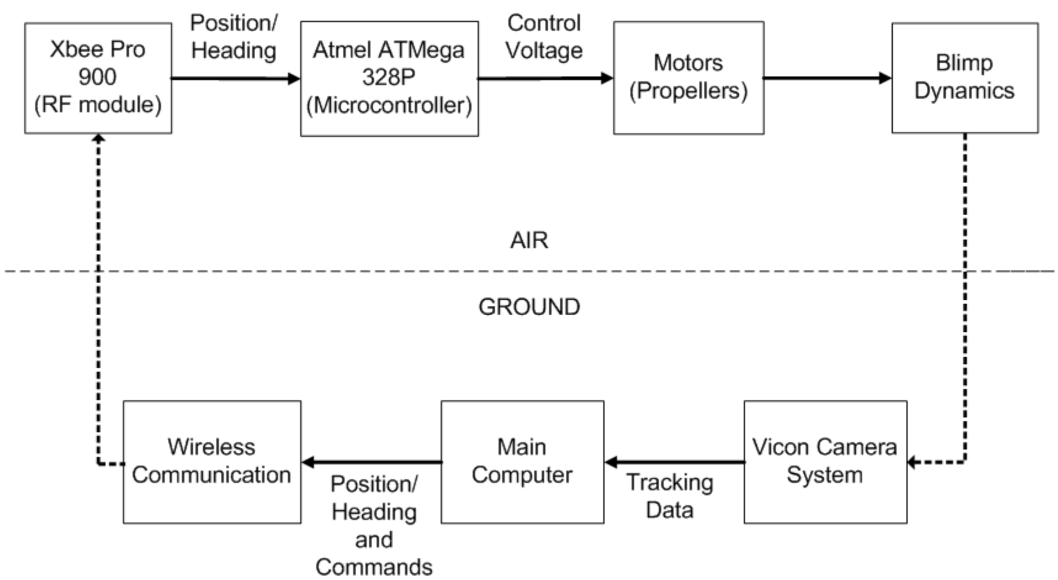


Figure 3: Control system architecture for autonomous blimp vehicle.

Preliminary Budget for Hardware and Electrical Components

The following table includes the components necessary for the construction of the overall system specified by the goals of this project. The customer has specifically requested purchasing these items in a staggered manner, acquiring the parts necessary to construct one blimp first. Once in it is clear that the primary and secondary goals can be satisfactorily reached, the remaining necessary components will be purchased. The anticipated components for the construction of the blimp and the implementation of the control system are listed in Table 1.

Table 1: Component list for blimp

Hardware	Manufacturer	Per Unit Cost ($)	Quantity	Total ($)
Arduino Main Board (w/ ATMega 238p)	Arduino	29.95	2	59.90
Digi xBee Pro 900 RF Modules	Digi	42.00	2	84.00
xBee Explorer USB	SparkFun Electronics	25.00	2	50.00
Mylar Blimp Envelopes	Mobile Airships	89.00	2	178.00
Ducted Fan Power System with Rotor	BP Hobbies	11.73	12	140.76
Misc Structural	N/A	50.00	1	50.00
PS2501-4 Optocoupler	California Eastern Laboratories	1.51	10	15.10
1 kΩ Resistor	NA	0.50	20	10.00
LMD18200T H-Bridge	National Semiconductor	17.78	5	88.90
.01µF Capacitor	NA	0.40	10	4.00
1µF Capacitor	NA	0.30	2	0.60
7.4 V Lithium Polymer TENERGY Battery	TENERGY	60.00	4	240.00
Cell/Lipo Shield	TENERGY	22.00	1	22.00
Battery Charger	TENERGY	25.00	1	25.00
LM7805 5V Regulator	FAIRCHILD Semiconductor	0.95	1	0.95
Total				969.21

Project Plan and Personnel Use

The Formation Flying Blimp project has been divided into four basic subsystems: Hardware, Software, Controls and Power. Each subsystem has also been assigned a leader. The role of the subsystem lead is to ensure that all tasks assigned to their particular system are completed to satisfaction by the specified deadline.

Project Leader: Matthew Walker

Hardware Subsystem Lead: Beth Boardman

Software Subsystem Lead: Kyle Odland

Controls Subsystem Lead: Maggie Wintermute

Power Subsystem Lead: Linh Bui

Preliminary Task List

The tasks for the project have been broken up by subsystem. Table 2 shows the necessary something that must be completed for each subsystem. Also included is the list of team members working on each task and the preliminary deadline for completion.

Table 2: Preliminary Task List for Formation Flying Blimps project

Hardware	Task	Members	Deadline
1	Identify and order necessary structural components, motors and propellers	All	4/9
2	Finalize motor configuration	Boardman, Walker, Wintermute	4/9
3	Thrust test motors for plant model	Boardman, Walker, Wintermute	4/16
4	Develop blimp and gondola CAD model	Boardman, Walker	5/7
5	Final blimp and gondola design	Boardman, Odland, Wintermute	5/14
6	Construct blimps	All	5/21

Software	Task	Members	Deadline
1	Develop VICON camera system interface	Boardman, Odland, Wintermute	4/16
2	Research and define software system architecture between VICON camera system, central computer and microcontroller	All	4/23
3	Establish WiFi communication between Microcontroller and Central Computer, validate with simple task test	Boardman, Odland, Walker	4/30
4	Develop Microcontroller to circuit board communication	Bui, Odland, Wintermute	5/7
5	Develop control law code	Bui, Boardman, Odland	5/19
6	Implement control law onto microcontroller	Bui, Odland, Walker	5/21
Controls			
1	Develop Plant Model	Bui, Walker, Wintermute	4/16
2	Develop Waypoint Tracking Control Law	Bui, Walker, Wintermute	4/30
3	Develop coordinated task and formation control law	Boardman, Odland, Walker, Wintermute	5/7
4	Develop Simulink Model for control law validation	Odland, Walker, Wintermute	5/14
Power			
1	Identify and order necessary electrical components	Bui, Walker	4/9
2	Research Microcontroller– actuator interface, battery configurations	Bui, Boardman, Odland	4/30
3	Preliminary circuit board design, validate via breadboard	Bui, Walker	5/7
4	Final circuit board design, order PCB	Bui, Walker	5/14
All			
1	Troubleshoot and integration	All	5/28
2	Initial Flight Test	All	6/1
3	Final Flight Test	All	6/4

Resources

“ATmega328P,” Atmel Corporation, 2010. [http://www.atmel.com/dyn/products/product_card.asp?PN=ATmega328P]

“EDF-50 Ducted Fan Power System with EDF-2020x3 Rotor (GW/EDF50),” BP Hobbies, 2009. [http://www.bphobbies.com/view.asp?id=B1098404&pid=gws109&img=l]

Hughes et. al "Distributed Space Systems Laboratory Blimp, EE/AA449 Final Report" June 13, 2008

“Rechargable Batteries and Chargers,” AllBattery.com, 2010. [http://www.all-battery.com/]

“Science Project Parts,” Mobile Airships Inc., 2007. [http://blimpguys.com/scienceParts.htm]

“XBee Explorer USB” Digi International Inc., 2010. [http://www.sparkfun.com/commerce/product_info.php?products_id=8687]

“XBee-PRO® 900 RF Modules” Digi International Inc, 2010. [http://www.digi.com/products/wireless/point-multipoint/xbee-pro-900.jsp#overview