Twin-Hull URRG Blimp Control for Low Altitude Surveillance Application

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Abstract. Blimp system with cameras is an appropriate method to conducts environmental surveillance, which offers the ability to hover at low altitude with less noise. However, blimps envelope causes large drag coefficient value compared to other aircrafts. Therefore, the structural design and motion control of the blimp system are very crucial thus contribute to the overall system performances. This paper presents the structural design and motion control method for low altitude surveillance system. The structural design of the Twin-hull blimp system (THCS) is separated into three parts, which are designs of blimp envelope, design of gondola and motion control mechanism. For the motion control, both open-loop and closed-loop control system are implemented into THCS for horizontal and vertical motion control. Several experiments with a real constructed blimp are performed in indoor environment to confirm the design performance and stability of THCS.

Keywords: blimp, aerial vehicles, control, airship, surveillance system.

1 Introduction

Airship is a Lighter-Than-Air (LTA) aircraft that able to float in the air using the buoyancy principle; the total weight is less than buoyancy forces of air that acting on it. The airship can be classified based upon the hull design (1) non-rigid (2) semi-rigid, and (3) rigid, production lifting force and payload ability. Generally, there are two airship types: the conventional type and unconventional type. The conventional airships have a streamline symmetric body with long drag shape, generate aerostatic lift by an envelope, lower payload capability and a power source. All the other types of airship that have different characteristics with conventional airships are classified as unconventional airships [1].

Recently, many researchers have been exploring back the blimp technology. The research fields of the blimp include surveillance or real time monitoring [2], the indoor blimps [3], the outdoor blimps [4] [5], wind hardness control [6], navigation control [7] [8]. A blimp is an ideal stable platform for low-altitude surveillance. It is much more stable than other aircraft such as helicopter and airplane. It takes the best advantage to provide high quality live video streaming. Blimp also able to hover and

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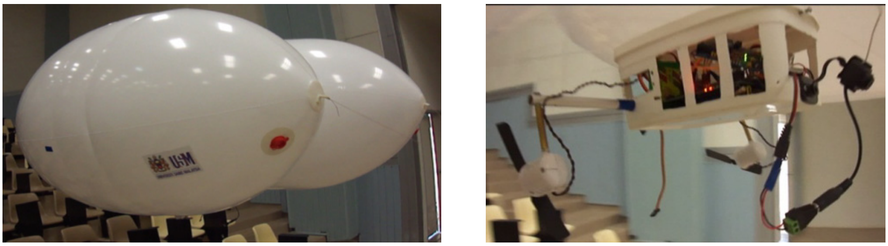
stay aloft from hours to day compared to other aerial vehicles. Unlike other aircraft, blimps are sustainable, which used low energy consumption. Blimps use lifting power of helium gas to keep them in the air and not the lifting power from an engine. In this design, electrical energy is used to power up the motors. Moreover, blimps are also generally much quieter than other aircraft hence reduce the sound pollution.

In this work, the blimp was used as a surveillance platform; it enables easier data gathering for an area. It will also capable to observe an area safely and quickly from sky [5]. Furthermore, the surveillance systems will also able produce a map thus contributes the path planning for an area. The blimp design was based on non-rigid airship using unconventional airship design. The non-rigid airships are often called "blimp." Unlike other rigid and semi-rigid airships, a blimp is an airship without an internal framework or keel to support the envelope shape. The hull depends on the helium gas to produce good shape.

This paper proposed a small structural design and motion control method for an indoor blimp. The development and stability performance of the blimp system will be discussed throughout this paper. Fig. 1 shows the blimp platform used in this experiment.



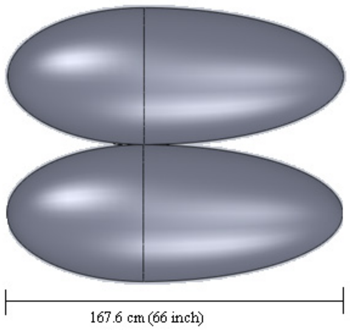
(a) (b)

Fig. 1. Surveillance system (a) Twin Hull design (b) Gondola

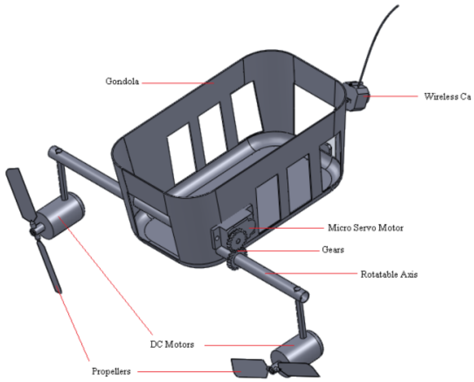
2 Structural Design

In this work, the structural design of a blimp is divided into three main parts, which are blimp envelope, gondola, and motion control mechanism. Blimp envelope design is focused on its size and shape. The size and shape of blimp envelope play the most important role for blimp to be able to float in the air. While the gondola holds and protects all the hardware on the blimp. The design was also equipped with two DC motors mounted on the gondola to control the motion of the blimp. A wireless camera is attached in front of the gondola for surveillance purposed.

The blimp design is based on unconventional airship design, which is used twin hull design as illustrated in Fig. 2(a). For twin hull design, two conventional envelopes with streamlined bodies are joined together without any solid structures. The main advantage in this design is the reduction of overall length for a given volume of gas. This means greater volume of gas can be used for this design to achieve the same overall length as conventional design. With the larger volume of gas, double envelope design leads to increase aerodynamic lift and payload capacity. Lifting force equation (1) is used to calculate the optimum blimp's size and payload capacity.



(a)



(b)

Fig. 2. (a) Blimp Envelope (b) Gondola and Motion Control Mechanism

$$F_L = Vg(\rho_{air} - \rho_{he}) - W_o \quad (1)$$

Gondola of a blimp is used to hold the hardware such as batteries, microcontroller, sensors, servo motor, wireless module and wireless camera. Two dc motors with the propeller are mounted on the gondola, where one motor on the left-hand side and the other one on the right-hand side. The structure of the gondola needs to be light and also strong. In choosing the size of the gondola, there are two considerations need to be consider. First, the space inside the gondola needs to be large enough to enclose all the electronic components and batteries. Second, the width of the gondola needs to be long enough for supporting the rotatable axis and the weight of the DC motors. We introduce open areas on the gondola surface in order to reduce the weight and enhance the performance of wireless communication. The propulsion system were equipped with two DC motors mounted at each side and connected to a rotatable axis to produce vertical take-off and landing (VTOL) capabilities. The angular position of rotatable axis is controlled by a micro servo motor as shown in Fig. 2(b). Two gears are used to join the servo motor and the rotatable axis, which allow the motors to perform precise pitch rotation.

3 Blimp Control System

The control system of the blimp is design for 2 modes which are manual control and automatic control. The manual control is implementing an open-loop control system, which directly controlled by an input signal without any feedback signals. On the contrary, automatic control is a closed-loop control system, which utilized feedback sensors to control the motion of the blimp. It used to control the altitude of the blimp.

As mention in the blimp structural, the blimp has two motors mounted at each side of the gondola. A servo motor is used to control the angular position of rotatable axis. In this case, only two angular positions are used for rotatable axis, which are 0° and 90°. The 90° of angular position used for vertical motion and 0° of angular position used for horizontal motion. Fig. 3 shows the block diagram of a closed-loop control system of altitude control.

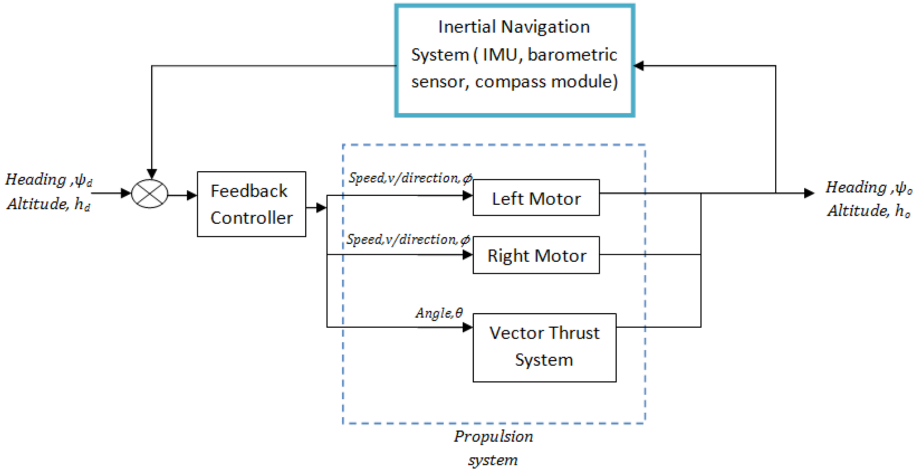


Fig. 3. Closed-loop Control System

The barometric pressure sensor is used as a feedback sensor for altitude control. The altitude's values that provided by this sensor is fed to the controller as the feedback signal. By comparing with the desired altitude that set by the user, the controller will drive the motors to the desired speed and direction, and lift the blimp to the desired altitude. Due to the sensitivity and stability of sensor's output, processing speed and other factors, it is impossible to lift the blimp to the altitude that exactly equals to desired altitude without any error. Therefore, a control limit is chosen for altitude control, which is plus-minus one meter. The permissible error range of altitude control is two meters.

4 Result and Discussion

In order to verify the capability of the developed blimp platform, we have done real time testing in a large indoor environment. In our experiments, the evaluations of system performance were done on altitude control and forward navigation of the blimp. In the altitude analysis, the real time output was recorded every 5 seconds starting from 0 s to 70 s for three different altitudes, which are 3 m, 4 m, and 5 m. Fig.4 shows the real time blimp output, while deviation value from desired altitude was stated in Table 1.

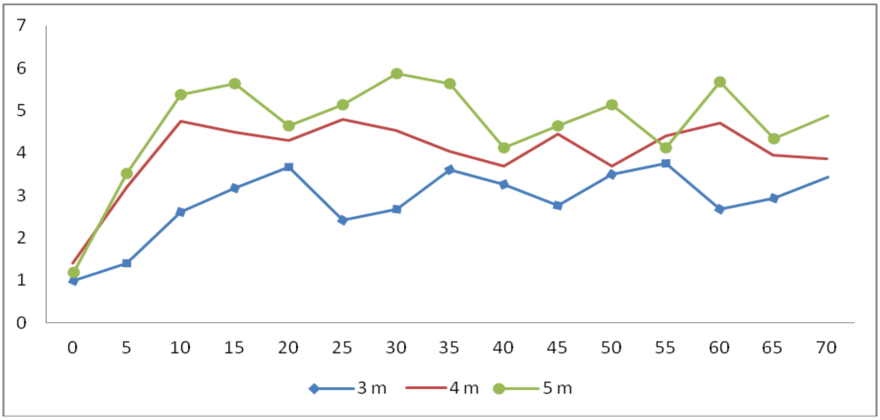


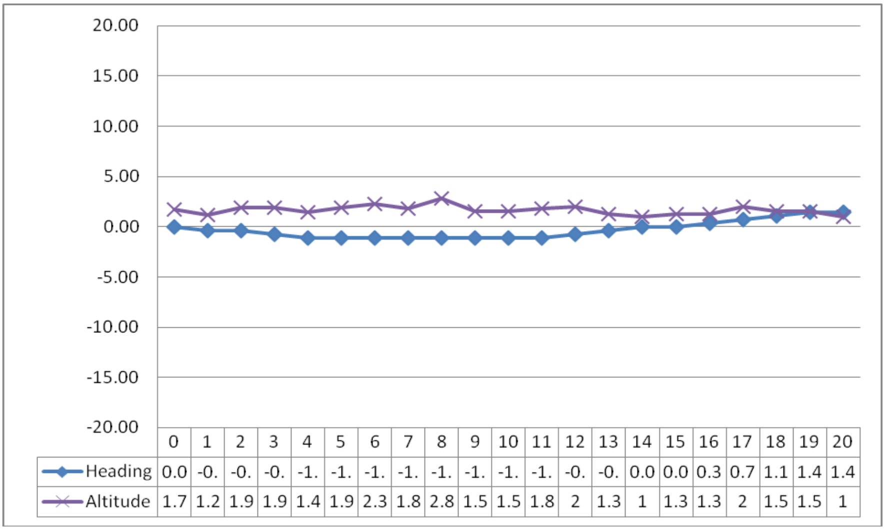
Fig. 4. Real-time output

The results show that altitude response produced an oscillation response to the maximum of 25 % deviation from the desired response. We can observe that this system was very sensitive to the environment due to buoyancy effect produced by the helium gas. However, the responses were able operate within acceptable altitude tolerance value.

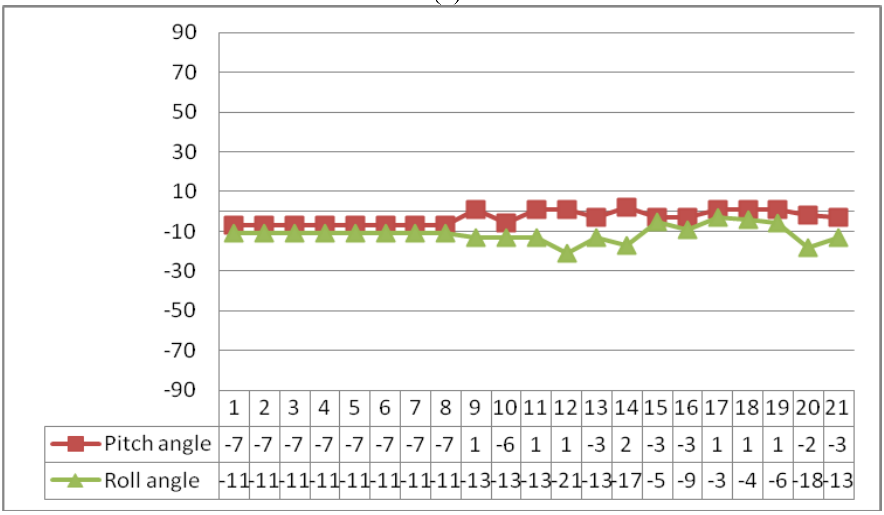
Table 1. Altitude performances

Time (s)	3 m		4 m		5 m	
	different	error (%)	different	error (%)	different	error (%)
5	1.6	53	0.8	20	1.48	29.6
10	0.4	13	-0.75	-18.75	-0.38	-7.6
15	-0.17	-6	-0.5	-12.5	-0.63	-12.6
20	-0.67	-22	-0.29	-7.25	0.37	7.4
25	0.58	19	-0.79	-19.75	-0.13	-2.6
30	0.33	11	-0.54	-13.5	-0.88	-17.6
35	-0.6	-20	-0.04	-1	-0.63	-12.6
40	-0.25	-8	0.3	7.5	0.88	17.6
45	0.25	8	-0.45	-11.25	0.37	7.4
50	-0.5	-17	0.3	7.5	-0.13	-2.6
55	-0.76	-25	-0.4	-10	0.88	17.6
60	0.33	11	-0.7	-17.5	-0.67	-13.4
65	0.08	3	0.05	1.25	0.67	13.4
70	-0.42	-14	0.13	3.25	0.13	2.6

In the navigation analysis, the stability testing for forward navigation is performed with initial altitude of 2 meters. The parameters used to analyze the stability performance include heading angle, pitch and roll angle, and altitude. The results are shown in Fig. 5. The pitch angle produces maximum output deviation of 8%, while heading generated only 1.5% yawing error with 0.4 altitude error.



(a)



(b)

Fig. 5. Graph of Effect of Parameters for Forward Navigation

From the overall analysis, we can conclude that the blimp design is able to navigate with acceptable response. Although the system were very sensitive to the real environment, proper design and control method will be able to help to generate good response thus produce good stability response. Thus this design offer more payload and easier to manage due to smaller size.

5 Conclusion

In this paper, we presented structural design and an approach motion control method of a blimp to conduct low altitude surveillance. We performed some experiments with a real constructed surveillance blimp in a large indoor environment. The twin-hull design was able to reduce the overall length of blimp and produced heavier payload capacity. The optimum size and payload capacity was calculated and successfully lift the blimp to desired altitude and compensated the disturbances. The motion control method presented in this paper was successfully controlled the motion of blimp in horizontal and vertical plane, and performed VTOL. Based on the experiment results, our blimp was able to navigate with acceptable response and conducts low altitude surveillance in the indoor environment. In future work, we would like to consider increasing the payload capacity, and making it possible to hover and navigate in outdoor environment.

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