An Aerial Robot System Tracking a Moving Object

Takehito OGATA* Joo Kooi TAN* and Seiji ISHIKAWA*

* Department of Mechanical and Control Engineering
Kyushu Institute of Technology

Sensuicho 1-1, Tobata, Kitakyushu 804-8550, Japan
(Tel : +81-93-884-3191; Fax : +81-93-884-3183)
E-mail : ogata@is.cntl.kyutech.ac.jp

Abstract: Automatic tracking of a moving object such as a person is a demanding technique especially in surveillance. This paper describes an experimental system for tracking a moving object on the ground by using a visually controlled aerial robot. A blimp is used as the aerial robot in the proposed system because of its locality in motion and its silent nature. The developed blimp is equipped with a camera for taking downward images and four rotors for controlling the progression. Once a camera takes an image of a specified moving object on the ground, the blimp is controlled so that it follows the object by the employment of the visual information. Experimental results show satisfactory performance of the system. Advantages of the present system include that images from the air often enable us to avoid occlusion among objects on the ground and that blimp's progression is much less restricted in the air than, e.g., a mobile robot running on the ground.

Keywords: Aerial robot, blimp, tracking, automatic tracking, image processing,surveillance

1. INTRODUCTION

Development of a technique for real-time tracking of a specified target automatically such as tracking a person in the crowd has become increasingly important for the security purpose. If we use, for the tracking, images obtained from a downward camera in the air (referred to as aerial images hereafter), we receive lots of advantages. For example, aerial images exclude occlusion among the objects on the ground to a large extent according to the height of the placed camera. If a camera is on a blimp, it may offer a convenient photographing system, since the blimp's progression is much less restricted in the air compared with, e.g., a mobile robot on the ground that must run on a road occupied by various obstacles. Although various techniques for detecting/tracking moving objects employing aerial images have been studied, most of the researches put their attention on a specified place where cameras are set fixed such as inside of a building [1].

In this paper, we propose a tracking system employing a blimp for tracking a specified moving object. A blimp is used as an aerial robot in the present system. It has recently become a noteworthy robot because not only of its locality in motion but also its silent nature as well as compactness[2], [3]. The designed blimp is equipped with a camera and rotors, and it controls its progression employing aerial images acquired by the camera. The produced blimp system is explained along with its software system. Performance of the system is examined by experiments.

The techniques are described in section2 and section3 and the experimental results are shown in section4. Finally the paper is concluded in section5.

2. CONFIGURATION OF THE BLIMP SYSTEM

Figure 1 shows the configuration of the developed blimp system. An entire system consists of a blimp and a remote PC for visually controlling movement of the blimp. The blimp and the PC mutually transmit and receive image data as well as instructions through a wireless communication system.

2.1. CONSTRUCTION OF A BLIMP

Photographs of the blimp are shown in Figure 2. The developed blimp consists of an envelope and a gondola. The envelope is a balloon filled with helium, and its shape is sphere whose diameter is 110cm. Moreover, it has a lift capacity of approximately 400g. The gondola has four rotors and a single CCD camera. The three rotors are used for horizontal movement, and the other for the vertical movement. The CCD camera is set downward at the gondola for

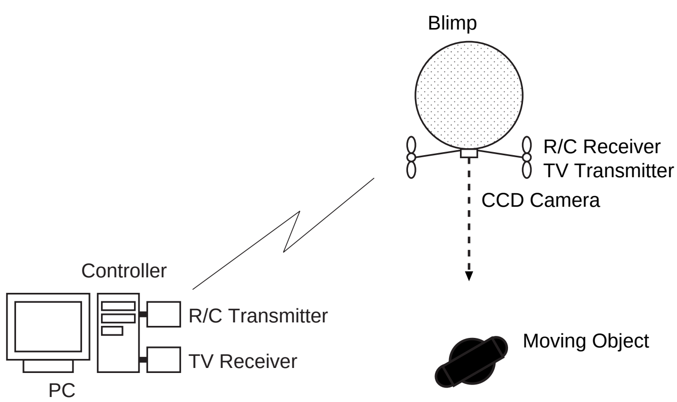


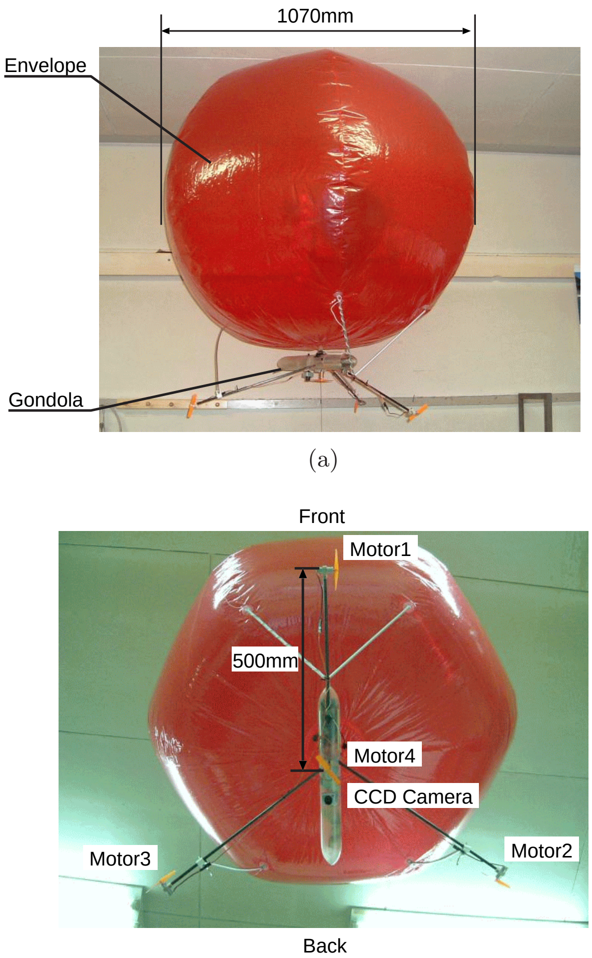
Figure 1. Configuration of the developed blimp system

capturing downward images.

The obtained images are transmitted to the PC on the ground through a TV-transmitter, from the obtained images Radio Control signal (it is composed of some pulses) is computed to acquire the control signals and then the signals is transmitted to the blimp through the Radio Control unit. Stable state of the blimp is realized by controlling it referring to the image information obtained from the camera. Specification of the main hardware is shown in Table1.

2.2. CONSTRUCTION OF SOFTWARE

The RT-Linux, one of the real-time operating system, is used as the operating system of the PC because the blimp must be controlled real time, and the Video for Linux, one of the API functions of Linux, is employed for capturing images from the blimp. The developed control program of the entire system contains two main task parts called the real-time program and the non real-time program, respectively. The real-time program part works mainly for the purpose of generating control signals to the blimp and finding/tracking a target from captured images. Non real-time program plays a role of capturing images in a periodic way, and controlling the real-time program for starting and stopping. Figure 3 shows construction of the developed programs.



(b)

Figure 2. Photograph of the blimp :(a) Front view, and (b) bottom view.

Table 1. Specification of the main hardware

Envelope	Diameter:1070mm (Buoyancy:500g)
CCD Camera	Keyence CK-200
Radio Control Unit	Futaba SkySport4
PC	Pentium III 866MHz 256MB
AD/DA Board	Interface PCI-3522A
Capture Board	I-O data GV-BCTV4/PCI

3. ALGORITHM OF VISUAL CONTROL

The real-time program has two tasks, and each task works in parallel. One task finds a target from obtained images by using image processing. An image is taken every 100 msec from the camera, and a target is found and captured in the center of the image. The flowchart of the image processing is shown in Figure 4. HSI transform is used for extracting the target by thresholding employing color information of the target. The range of HSI of the target is obtained by several experiments. Equation of transformation from HSI to RGB

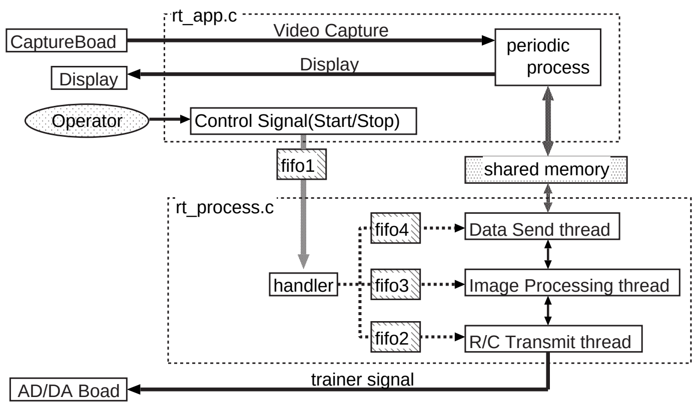


Figure 3. Diagram of the programs

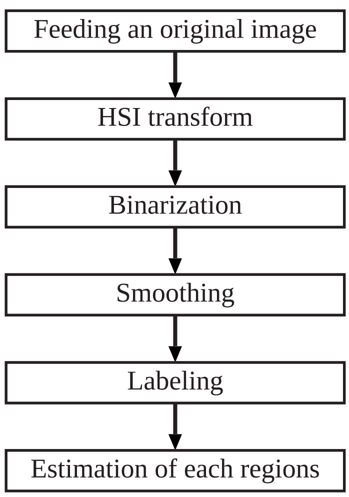


Figure 4. Flowchart of image processing

is given as follows:

$$
\begin{aligned}
I &= 0.299R + 0.587G + 0.114B \\
C_r &= R - I \\
C_b &= B - I \\
H &= \tan^{-1}\frac{C_r}{C_b} \\
S &= \sqrt{{C_r}^2 + {C_b}^2}
\end{aligned}
$$

where, R is red, G is green, B is blue, H is hue, S is saturation, and I is intensity. C_r and C_b are chrominance difference signals. Some kind of information is used for estimating all regions obtained by labeling process. Information used in the estimation is the area, perimeter, roundness, position (x, y) , velocity $(\frac{dx}{dt}, \frac{dy}{dt})$, and the average of intensity.

The other task generates radio control signals for tracking the found target. The characteristics of the amplifiers, motors and batteries used for the blimp vary little by little. Thus, for generating control signals of the blimp, we use the velocity type PID control method to calculate the horizontal driving force and the moment of the blimp. Then we calculate the torque of the each of four motors from the horizontal force and the moment. The equation of the torque is given as follows:

$$
\begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix} = \begin{bmatrix} 1 & \cos(\frac{2}{3}\pi) & \cos(\frac{4}{3}\pi) \\ 0 & \sin(\frac{2}{3}\pi) & \sin(\frac{4}{3}\pi) \\ \frac{1}{R} & \frac{1}{R} & \frac{1}{R} \end{bmatrix}^{-1} \begin{bmatrix} f_x \\ f_y \\ T \end{bmatrix}
$$

where, $t_1, t_2, t_3$are torques of the motors, $f_x, f_y$are the horizontal driving force, $T$is the moment of the blimp, and R is the radius of the blimp. Relation of each variable is shown in Figure 5.

Using only a single camera, we cannot obtain information on the height of the blimp. So we use ON/OFF control method in controlling vertical movement. The torque of the motor generating vertical movement is obtained by the following equation:

$$
t_4 = \begin{cases} T_{up} & \cdots \quad A \geq A_{max} \\ 0 & \cdots \quad A_{min} < A < A_{max} \\ T_{down} & \cdots \quad 0 < A \leq A_{min} \end{cases}
$$

where t_4 is the torque of the motor, A is the area of the target, A_{max} and A_{min} are threshold values of A. For example, if the area of the target becomes larger than a threshold value $(A \geq A_{max})$, the blimp goes up, and vise versa.

4. EXPERIMENTAL RESULT

4.1. HOVERING EXPERIMENT

"Hovering" means staying in the same place in the air. In the hovering experiment, blimp is controlled so that it keeps staying above the location between the orange and green landmarks. Experimental results are shown in Figure 6.

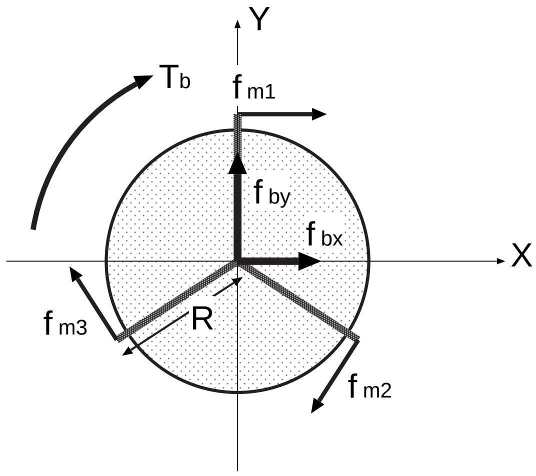


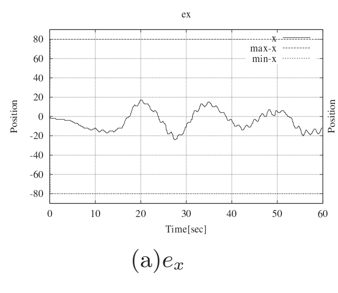
Figure 5. Movement of the blimp

4.2. TRACKING EXPERIMENT

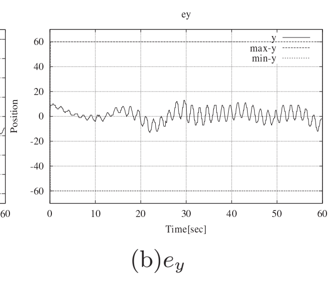
Employing the proposed system, tracking was performed of an object as a human model moving around on the floor of the laboratory. Figure 7 shows the photograph of tracking object. The blimp moved horizontally and/or vertically to follow the object successfully according to the visual feedback and with the velocity type PID control. Figure 8 shows some photos of the tracking experiment.

5. DISCUSSION AND CONCLUSIONS

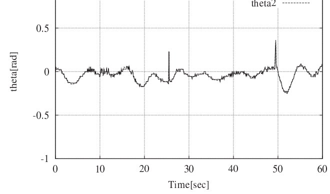
A technique was proposed for tracking/detecting a specified object employing a visually controlled aerial robot. A blimp was employed as an aerial robot in the developed system, because of its locality in motion, silent nature, and compactness. The technique was examined by experiments employing a moving object as a human model and satisfactory result was achieved. Tracking experiment of a real per-



(a)e_x



(b)e_y



(c)θ

Figure 6. Experimental result of hovering

Figure 7. Tracking object

son is going to be done employing the presented aerial robot system. Advantages of the present system include that an aerial robot can avoid occlusion among objects on the ground to a large extent by aerial images and that the direction of an aerial robot's progression is not restricted in the air than a mobile robot, e.g., running on the ground containing various obstacles.

References

[1] M. Sakata, Y. Yasumuro, M. Imura, Y. Manabe, K. Chihar, "A location awareness system using wide-angle camera and active IR-tag," *Proceedings of IAPR Work-Shop on Machine Vision Applications*, pp. 522-525, 2002.

[2] H. Zhang, J. P. Ostrowski,"Visual Servoing with Dynamics: Control of an Unmanned Blimp,"*Proceeding of IEEE International Conference of Robotics and Automation* , pp.618-623,1999.

[3] F. Iida, "Goal-directed navigation of an autonomous flying robot using biological inspired cheap vision," *Proceedings of the 32nd International Symposium on Robotics*, 2001.

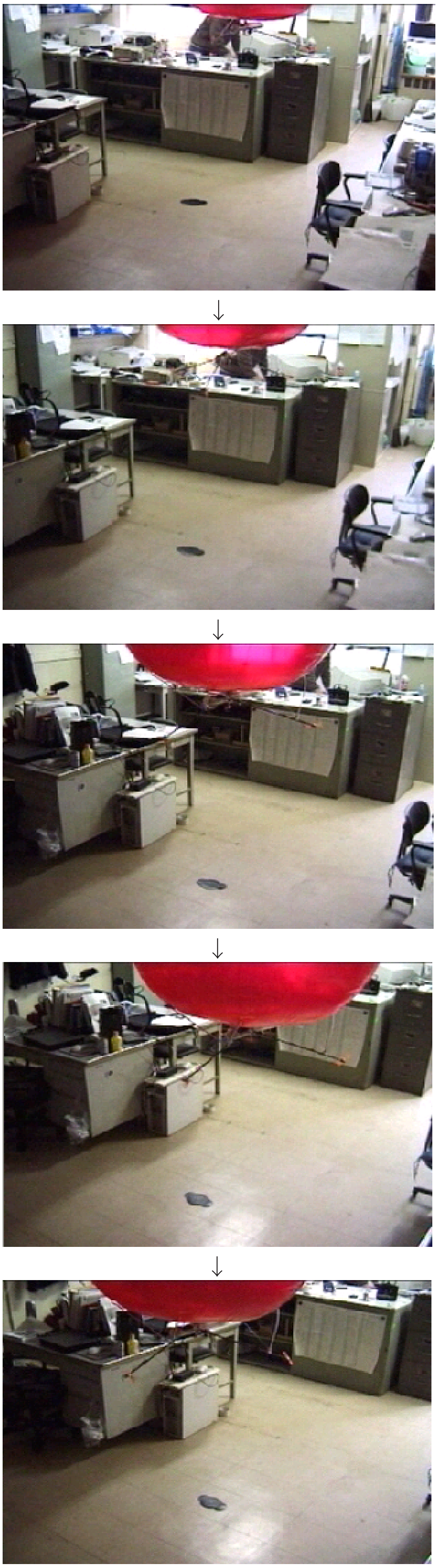


Figure 8. Tracking experiment