International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 22 (2017) pp. 12955-12960

Location Holding System of Quad Rotor Unmanned Aerial Vehicle(UAV) using Laser Guide Beam

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Abstract

Recently, unmanned aerial vehicle (UAV) has been developed in industrial applications. UAV usually has fixed-wing aircraft and rotor-type aircraft. The rotor-type aircraft is divided by single-rotor type and multi-rotor type. Quad-rotor aircraft (QRA) is flying using rotor with two pairs of symmetrical to each other. In this study, we chose to quad-rotor aircraft, because it is able to do vertically take-off and landing and hovering function. UAV are used at hard-to-reach areas for human, such as transmission tower or high-rise buildings. In the vicinity region of these buildings, radio disturbance by high-voltage power lines tends to occur in. Generally, GPS is used in order to detect the UAV position. Hence GPS cannot detect UAV position in the radio disturbance areas. In this paper, we show location holding system of UAV using laser guide beam. That system enables a multi rotor helicopter to hover in the radio disturbance areas distributed around high-rise buildings. This system consists of a photo-transistor array position sensor mounted on in the UAV and laser guide beam on the ground.

Keywords: Unmanned aircraft vehicle (UAV), quad-rotor, location holding system, laser guide beam

INTRODUCTION

Unmanned aerial vehicle (UAV) has mainly been developed for military purpose. In recent years, it has been used in various forms such as meteorological observation, environmental and forest fire monitoring, communication relay, etc. in order to provide safety and convenience to human's real life. The research has been done extensively to obtain visual information in an environment where humans have a difficulty in accessing, such as disaster areas, mountainous regions and high-rise buildings [1].

Since UAV can perform missions in such environments, rotary-wing aircraft may have a more efficient ability to perform missions than fixed-wing aircraft. Fixed-wing aircraft needs a wide landing space, whereas rotary-wining aircraft has hovering functions and relatively high 6-DOF (Degree of Freedom) in areas where people are difficult to access. Rotary-wing aircraft can be divided into a single rotor-type, coaxial rotor-type and a quad rotor-type, etc. depending on shapes [2]. Single rotor-type aircraft is a craft in a general chopper form. It raises lift by rotating a single rotor. Coaxial rotor-type aircraft rotates a rotor through the upper and lower of a single axis to raise lift, and the counter-torque is attenuated by reverse rotation of the rotor. And quad rotor-type aircraft attenuates counter-torque and generates lift by two pairs of rotors symmetrical to each other. Quad rotor-type aircraft attenuates counter-torque without the tail rotor of a single rotor-type and has the advantage of efficiency since it cause relatively large lift [3]. In this study, quad rotor-type aircraft was selected as main material of this research since they it can be more efficiently operated, compared to other types of rotary-wing aircraft.

To find out the location information of UAV, GPS (Global Positioning System) is most commonly used. In order to maintain a hovering state while flying, it is necessary to control the position by obtaining the location information on GPS from MCU (Micro Control Unit) or to have a high level of altitude control by such a sensor as IMU (Inertial Measurement Unit). However, the structure of quad rotor aircraft (QRA) selected in this study consists of a very complex system, so it is difficult to express these movements. For this reason, it is not easy to design a controller for ideal hovering without using GPS [4].

Because the sensitivity of the GPS receiver is reduced by interference in the vicinity of the transmission tower, great difficulties occur in the control of UAV. Moreover, even by high-rise buildings in urban areas, there is a failure to receive the GPS data. If it is impossible to control the UAV in a stable position, the aircraft can collide with structures and it can result in damages to aircraft or personal injuries. Therefore change of position measuring method using GPS is required. In order to estimate the position of UAV without disabilities in an electric wave-shaded region, we proposed a location holding system, which consists of a laser guide beam and photo-transistor array.

SYSTEM OF QUAD ROTOR VEHICLE

Figure 1 shows the structure and specifications of the proposed QRA with location holding system. Quad rotor is multi-rotor copter with four arms, each of which have a motor and a propeller at their ends. In quad rotor, two of the propellers spin in one direction (clockwise) and the other two spin the opposite direction (counterclockwise) and this enables the machine to hover in a stable formation [5-8]. The dimension of QRA used in this experiment is determined by a width of 62cm, a length of 62cm, and a height of 40cm in which a DC brushless motor is used as a power source. Multiwii software is used to the MCU for controlling an aircraft.

Description	Value
Width	620mm
Length	620mm
Height	400mm
Weight	0.8Kg
Payload	1.2Kg
Propeller	10″ x 4.5″

Figure 1: Structure and specifications of QRA

The control board processes data input from the sensor, generates PWM signals, and transmits data by wireless. The control board includes MCU (Atmel, Atmega 2560), 2.4GHz band - RC receiver (Walkera, RX701), wireless communication module for transmitting real-time data to PC and a selector (TOSHIBA, TC74VHC244) to select the flight mode of QRA.

LOCATION HOLDING SYSTEM

The block diagram of location holding system is shown in Figure 2. The proposed system enables hovering flight using a laser diode without disorders, as it automatically copes with disturbance and maintains hovering flight. The system needs four control signals: Throttle, Aileron, Elevator, Rudder. Of these signals, the throttle propel the aircraft upward or make it fall. Aileron controls roll of the aircraft, and Elevator controls pitch. Rudder controls yaw movement.

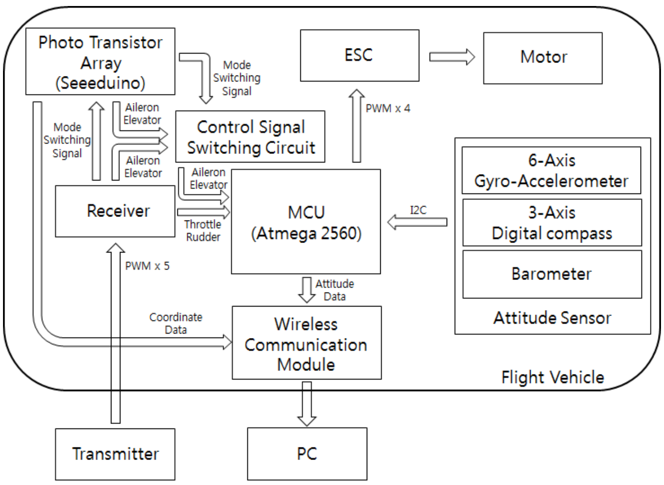


Figure 2: Block diagram of location holding system

Preferentially, the aircraft makes a flight by a control signal sent from a RC transmitter. Then, the operator transmits five control signals. Of these signals, Throttle and Rudder control signals are passed to the controller, and Aileron and Elevator control signals are delivered to the selector. And mode conservation signals are passed through the photo-transistor array, converted into an on-off signal, and delivered to the selector. Photo-transistor arrays identify the location of the aircraft independently from the control signal and the RC transmitter. And generates Aileron and elevator control signals. Then, they deliver them to the selector. For the selector, if the mode signal is located at "Off," it selects RC transmitter's Aileron and Elevator control signals and delivers them to the controller. If it indicates "On," the selector delivers the control signal from the photo-transistor array to the controller. Then, the aircraft comes to fly in a location holding mode. During flight, data are sent to the PC in real-time through a wireless communication module.

CONFIGURATION OF HARDWARE SYSTEM

Figure 3 shows a configuration of location holding system where the quad rotor aircraft, the laser guide beam, and the photo-transistor array are illustrated. The top of the figure on the left shows a QRA and at the bottom of the aircraft, the photo-transistor array is attached to look at the ground. The laser guide beam is irradiated to face the center of the aircraft. The figure on the right shows the photo-transistor array faced up.

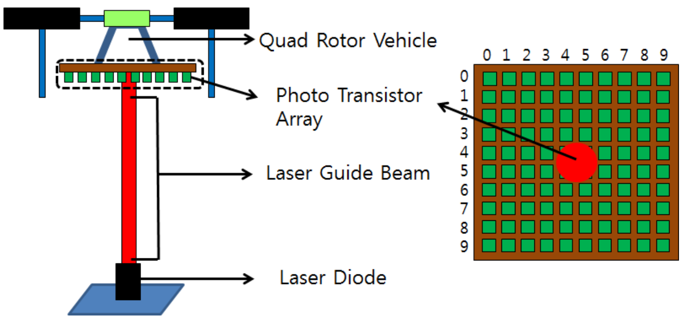


Figure 3: Configuration of location holding system

To fix the location of the flying aircraft without the GPS equipment, we need the means to identify the reference point. As the means to figure out the reference point, we need to install the laser guide beam to the area where the laser guide beam should be fixed and to ensure that the aircraft looks for the reference point and flies without departing from the reference point. For the system, the laser diode (Edmund Optics Inc. NT85-226) with the wavelength band of 650nm and the photo-transistor (New JRC, NJL7502L) with 10 x 10 array were used. When the control signals of Ailerons and Elevator are transmitted by controller of the aircraft, the aircraft is moved oward the center of the aircraft. Then, the photo-transistor array can look for a laser guide beam and the beam can be located in the center of the photo-transistor array.

The diameter of the laser beam is very small and the size varies depending on the distance. Thus, the beam expander (Edmund Optics Inc. NT55-577) was connected to the laser diode to zoom and to fix the diameter. Then it was fixed with a diameter of about 2.6cm. The gap between the photo-transistor of the photo-transistor array was 1.5cm horizontally and vertically, and the size of the entire array was approximately 15 x 15cm. The array was made so that one to four sensors to the maximum can respond by the laser beam with a diameter of 2.6cm.

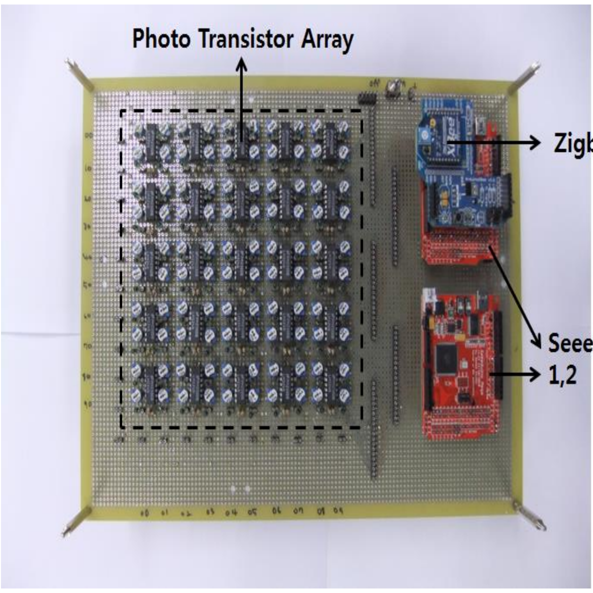


Figure 4: The assembled photo-transistor array

Figure 4 shows the assembled photo-transistor array which consists of two MCUs (Arduino, Seeeduino) to accommodate 100 transistors and Zigbee to transfer the coordinate system of the photo-transistor array to the PC in real time. The used photo-transistor responds in the visible region but does not responds to different light besides the laser guide beam. To eliminate the change of the output according to the distance, variable resistors and OP-Amp (LM324) was used. The manufactured array was tested by differentiating the distance of laser diode to test the change of the output up to 30m. From its results, the change of the output was not found.

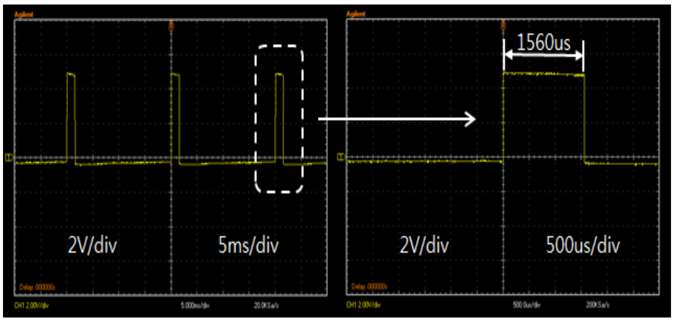
SYSTEM ALGORITHM

To pinpoint the current position of QRA, the coordinates were set up with horizontally (0-9) segments and vertically (0-9) segments to photo-transistor sensors in a 10x10 array.

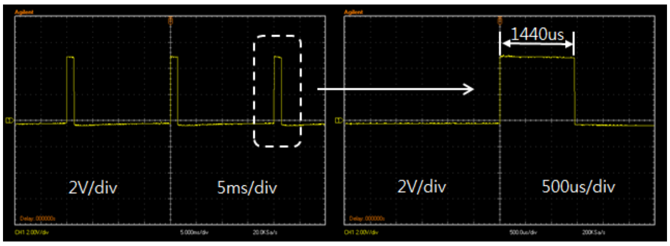
(0, 0)	(0, 1)	(0, 2)	(0, 3)	(0, 4)	(0, 5)	(0, 6)	(0, 7)	(0, 8)	(0, 9)
(1, 0)	(1, 1)	(1, 2)	(1, 3)	(1, 4)	(1, 5)	(1, 6)	(1, 7)	(1, 8)	(1, 9)
(2, 0)	(2, 1)	(2, 2)	(2, 3)	(2, 4)	(2, 5)	(2, 6)	(2, 7)	(2, 8)	(2, 9)
(3, 0)	(3, 1)	(3, 2)	(3, 3)	(3, 4)	(3, 5)	(3, 6)	(3, 7)	(3, 8)	(3, 9)
(4, 0)	(4, 1)	(4, 2)	(4, 3)	(4, 4)	(4, 5)	(4, 6)	(4, 7)	(4, 8)	(4, 9)
(5, 0)	(5, 1)	(5, 2)	(5, 3)	(5, 4)	(5, 5)	(5, 6)	(5, 7)	(5, 8)	(5, 9)
(6, 0)	(6, 1)	(6, 2)	(6, 3)	(6, 4)	(6, 5)	(6, 6)	(6, 7)	(6, 8)	(6, 9)
(7, 0)	(7, 1)	(7, 2)	(7, 3)	(7, 4)	(7, 5)	(7, 6)	(7, 7)	(7, 8)	(7, 9)
(8, 0)	(8, 1)	(8, 2)	(8, 3)	(8, 4)	(8, 5)	(8, 6)	(8, 7)	(8, 8)	(8, 9)
(9, 0)	(9, 1)	(9, 2)	(9, 3)	(9, 4)	(9, 5)	(9, 6)	(9, 7)	(9, 8)	(9, 9)

Figure 5: The coordinates of photo-transistor array

Figure 5 shows the coordinates of each of photo-transistors in the array. In the case where a large number of photo-transistors reacted, the array was set up to recognize the smallest value first. From the reaction of laser guide beam as shown in Figure 5, the location of the aircraft was determined on the basis of coordinates (4, 4) and the aircraft was moved by sending PWM signals so that it could return to a reference point. For example, if the aircraft has moved to the coordinates (1, 8) by disturbance, the aircraft is moved so that it can return to a reference points by transmitting control signals of Aileron and Elevator to move (1, 8) → (4, 4). The control signal to move the aircraft from the coordinates (1, 8) to (4, 4) was shown in Figure 6. In the case of the Aileron control signal, if it becomes larger than the reference, the rotational speed of the left rotor of the aircraft becomes faster and then it flies to the right. If it becomes smaller, it flies to the left as opposed. In the case of the Elevator control signal, if the signal becomes larger than the reference, the rotational speed of the rear rotor becomes faster and it comes to fly forward. On the contrary, if it becomes smaller than the reference, it comes to fly backward.



(a) Aileron control signal



(b) Elevator control signal

Figure 6: Aileron and Elevator control signal

The cycle of the aileron and elevator control signals was set at 50 Hz, and the size of the signals was set at 1500 μs. The generating cycle of the control signal was not established. Aileron and Elevators signals that have passed the selector and Throttle and Rudder signals from the RC transmitter were regenerated as signal to control each rotor through the controller. In this case, the cycle was 100 Hz.

FLIGHT EXPERIMENTAL RESULTS

Normal flight mode:

Figure 7 shows the graphs representing the control signals sent to the aircraft through the RC transmitter by the pilot, while Figure 8 shows the PWM signals to control each rotor generated at the controller. As can be seen in Figure 7, a number of unnecessary control signals and control signals larger than necessary have been generated because the human pilot operates the levers of the RC transmitter to guide the aircraft to hover over the laser-guided beam. That is why the signals controlling the rotors showed massive oscillation as represented by Figure 8, which made the vehicle's motion larger and also made it difficult to stabilize the hovering motion. The rudder control signal generated at sampling time 500 represents the ignition motion for the rotor, and the increase and decrease of the throttle control signal respectively at sampling times 800 and 3600 represent taking off / landing motion of the vehicle.

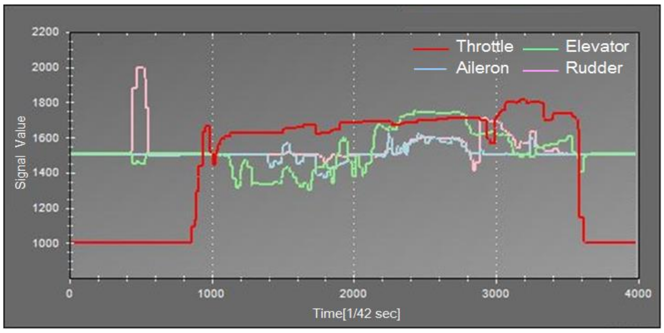


Figure 7: RC transmitter control signals

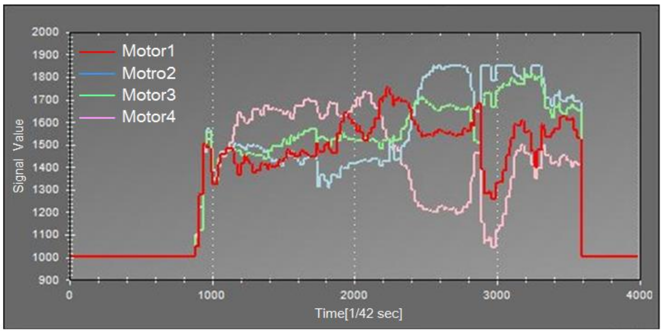


Figure 8: PWM control signals of rotors

Location holding flight mode:

Figure 9 represents the aileron and elevator control signals which have been generated based on the throttle and rudder control signals sent to the aircraft through the RC transmitter by the pilot and the coordinate value from the photo-transistor arrays. The graphs at the bottom are the magnified representations of the aileron and elevator control signals. The rudder control signal generated at sampling time 300 represents the rotor ignition motion, and the throttle control signals are transmitted only when taking off and landing. Compared with the experiment on the normal flight mode, there was no unnecessary movement of the throttle and rudder control signals as the RC transmitter was not operated after take-off. It was also found that the aileron and elevator control signals show consistent movement and stable change.

Figure 10 shows the rotor control signal generated by entering the throttle and rudder control signal transmitted from the transmitter and the aileron and elevator control signal from the photo-transistor arrays into the controller of the quad rotor vehicle. The signals show smaller changes except when taking-off and landing, and the output was also found to be stable.

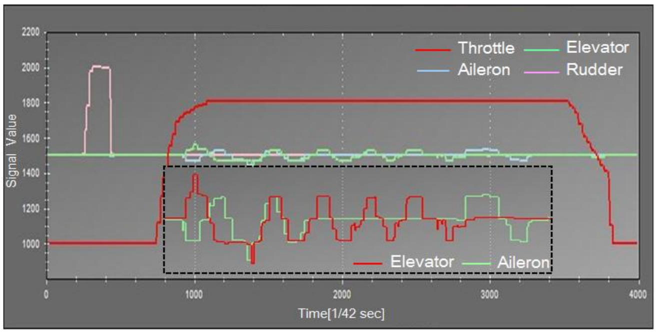


Figure 9: RC transmitter control signals

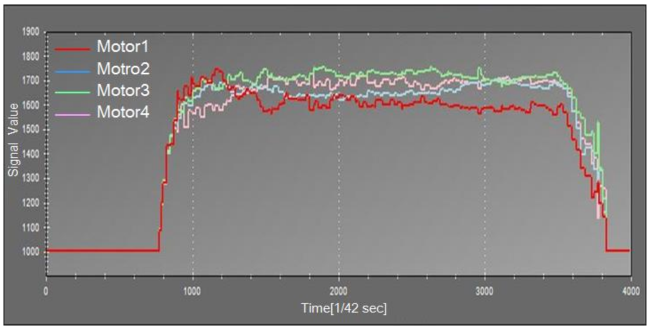


Figure 10: PWM control signals of rotors

Flight moving path:

The coordinate values of the test quad rotor vehicle position detected by photo-transistor array are transmitted to the PC above the ground in real time via a wireless communication module. Through these coordinate values, the moving path of the aircraft is identified within the range of photo-transistor, and the stability of the hovering can be checked

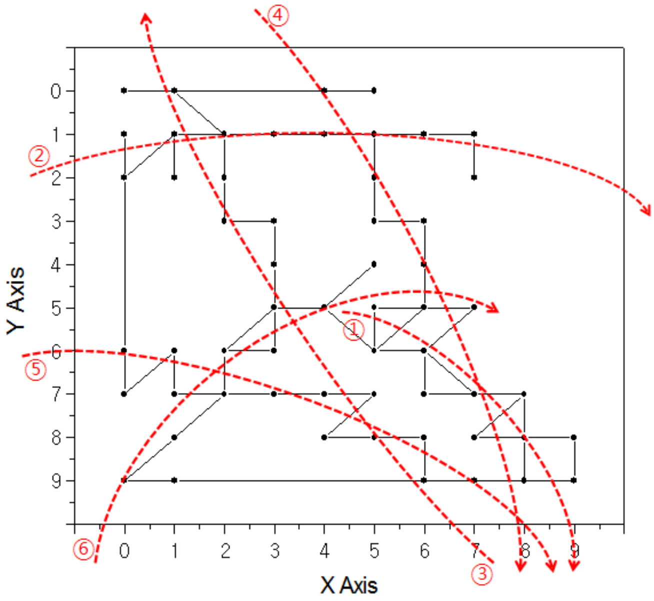


Figure 11: Moving path of the aircraft (normal flight mode)

Figure 11 represents the moving path of the aircraft in normal flight mode experiment, which was conducted in the status in which the laser guide beam from the center of the aircraft can be investigated. The results showed that the aircraft deviated from the coordinates five times through the entire fight. As identified in the results of analyzing data in the normal flight mode, stable hovering was not achieved since the movement was large and immediate countermeasures were not taken.

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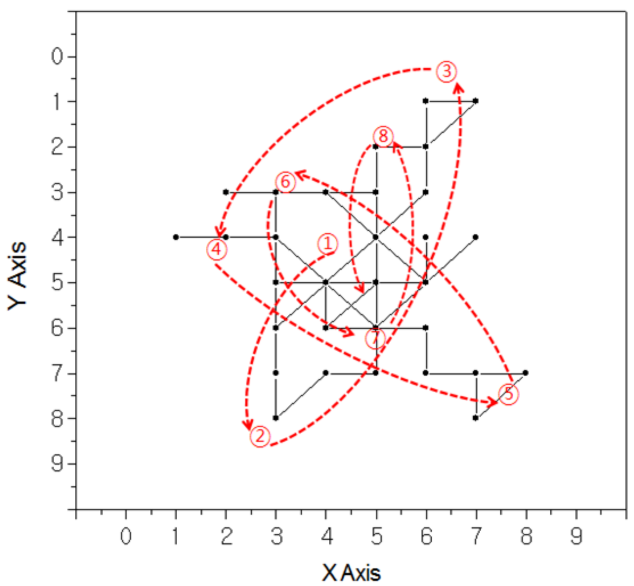

Figure 12: Moving path of the aircraft (location holding flight mode)

Figure 12 represents the moving path of location holding flight mode. As the case with normal flight mode test, an experiment was conducted after having the laser guide beam of the quad rotor vehicle investigated to the center. As shown in Figure 12, it was identified that as the control signals are transmitted appropriately and quickly according to the movement of the aircraft, the aircraft makes a flight, while maintaining stable hovering within the range of photo-resistor array (15 x 15cm) without deviating from the coordinate range.

CONCLUSION

This paper dealt with the research on the system which enables stable location holding using laser diode and photo-transistor that is not blocked in radio-shaded area, targeting a quad rotor vehicle. For an actual flight experiment, aircraft, photo-transistor array and attitude control test-bed were manufactured. In addition, the control signal switching circuits were configured to enable the switch of normal flight mode and holding flight mode during the flight, thereby implementing effective flight.

The dynamic characteristics of the quad rotor vehicle could be identified through an analysis on the data obtained from a sensor based on the actual flight experiments. In addition, the location of aircraft and its direction of movement was figured out within the rage of the array and the stability of hovering was identified through the laser guide beam and photo-resistor array.

In normal flight mode experiment, the accuracy of data is considered to be low due to the lack of quad rotor vehicle pilot' operational proficiency. However, it was identified that the pilot who was poor at operating the aircraft in normal flight mode experiment succeeded in conducting stable hovering flight, which demonstrates the excellence of the location holding system.

On the quad rotor vehicle manufactured in this paper, devices other than the photo-transistor array were not mounted due to the low performance of the rotor, which led to the non-acquisition of other information such as images during the flight experiments. In this regard, additional researches that can be applied in real life need to be done after enhancing the performance of the aircraft. In addition, it is required to conduct a study on the development of a system that can be utilized in a wider space outside from the confined space due to the fixed laser guide beam.

REFERENCES

[1] Pedro Castillo, Alejandro Dzul, Rogelio Lozano, "Real-time stabilization and tracking of a four-rotor mini rotorcraft", IEEE Transactions on Control Systems Technology, vol.12, no. 4, pp. 510-516, 2004.

[2] Pedro Castillo, Rogello Lozano and Alejandro Druz,

"Modeling and control of mini-flying machines, 1st Ed., Springer-Verlag London Ltd., 2005.

[3] Bora Erginer and Erdinc Altug, "Modeling and PD control of quadrotor VTOL vehicle", IEEE explore of Intelligent Vehicle Symposium, pp. 894-899, 2007.

[4] Mokhtari. A., Benallegue. A., "Dynamic Feedback Controller of Euler Angles and Wind Parameters Estimation for a Quadrotor Unmanned aerial vehicle", Robotics and Automation, Proceeding. ICRA '04, IEEE International Conference, pp. 2359-2366, 2004.

[5] Tommaso Bresciani, Modeling, "Identification and Control of a Quadrotor Helicopter", M.S. Thesis, Lund University, 2008.

[6] F. Lin, W. Zhang and R. D. Brandt, "Robust Hovering Control of a PVTOL Aircraft", Control System Technology, IEEE Transaction on, vol. 7, no. 3, pp. 343-351, 1999.

[7] H. Bouadi, M. Bouchoucha and M. Tajine, "Sliding Mode Control Based on Backstepping Approach for an UAV Type-Quadrotor", International Journal of Applied Mathematics and Computer Sciences, vol. 4, no. 1, pp. 12-17, 2008.

[8] Li-Chun Lai, Chi-Ching Yang and Chia-Ju Wu, "Time-Optimal Control of a Hovering Quad-Rotor Helicopter", Journal of Intelligent and Robotic System, vol. 45, no. 2, pp. 115-135, 2006.