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Direct Touch Operation Method for Flying Cargo System Based on Multi Rotor Helicopter

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***Abstract*—**We present the flying cargo system based on multi-copter. This system is designed for transporting at irregular ground. Two types of specialized "Direct Touch Operation" method for flying cargo system were tested. The first flight mode is "Direct push operation", and second flight mode is "Touch/Auto Operation". We report the results of both flight modes. These are intuitive operation method by which any one can operate flying cargo system. Flying cargo can do transportation in horizontal and vertical directions without topographical effect.

***Keywords*—**Flying cargo, multi copter, direct pushing, direct touch input.

I. Introduction

HOW to realize quick and safe transportation in irregular ground caused by a natural disaster is one of the main issues of transportation on rescue mission. One solution is rough terrain dumper which is used popular transportation in irregular grounds. Rough terrain dumper has superior performance than standard vehicle. It has climbing angle less than or equal to 30 degrees; it can get across short ditch and shallow river (fording). **Figure 1** shows examples of how rough terrain dumper is used. But it can't access to the area such as collapse, wide ditch, deep river and the isolated place caused by collapse of bridges (**Figure 2**).

In such case, helicopter is used for transportation. Helicopter has the hovering ability which is effective for transportation. But helicopter transportation is subject to the restriction of aviation law and influence caused by downwash. Also the running cost of helicopter transportation is very expensive.

On the other hand, UAV (unmanned aerial vehicle) such as unmanned helicopter is the excellent vehicle which can go into the area where ground vehicle can't go into, and it is used as aerial investigation platform to estimate disaster damage. Also UAV can transport small quantities of materials. However, UAV operation needs maneuvering technique, and it has disadvantages that flight duration is very short as compared to manned aerial vehicle. Especially, UAV operation is very difficult, and it requires long time to master maneuvering technique.

When the UAV is at so far position to be un-visible, it is very difficult for inexperienced operator to control the UAV despite of equipped assistance system in refs [1-4] such as attitude controller or auto-pilot. This difficulty is caused by the distance between the operator and the UAV. UAV operation difficulty increases continuously with the distance. Conversely, UAV operation becomes easy when the operator handles it directly by hand. And auto-return function enables safety returning and landing when inexperienced operator loses the UAV in distant location.

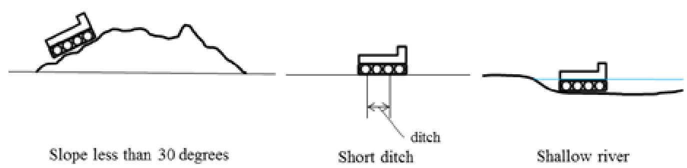

Figure 1 Rough terrain dumper

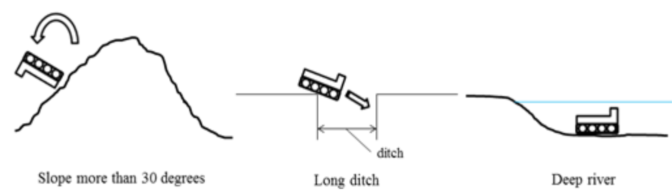

Figure 2 Irregular grounds in which rough terrain dumper is inadequacy

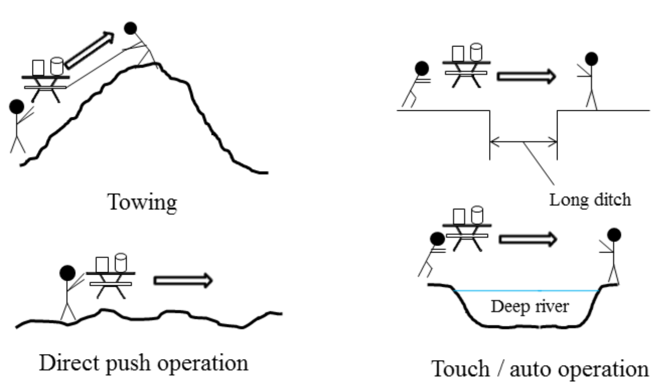

Figure 3 Concept of flying cargo system

According to the above considesration, we present the flying cargo system based on multi-copter. This system is designed for transporting at irregular ground. Two types of specialized "Direct Touch Operation" method for flying cargo system were

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tested. These are intuitive operation method by which any one can operate flying cargo system. Flying cargo can do transportation in horizontal and vertical directions without topographical effect. **Figure 3** shows the scenes of flying cargo transportation examples.

II. Experimental Setup

Figure 4 shows the test quad rotor helicopter (QRH). Propeller guard (material: EPP) and pressure sensors (Interlink Electronics: FSR-406) are mounted on QRH (Rapido Kobo: RapidoX650). ArduPilotMega2.5 (3DRobotics) with arducopter 3.1 (DIY Drones: freeware) is used as flight controller (FC) for test QRH. **Figure 5** shows the experimental setup system FC is linked with PC via XBee (Digi international: XBee Pro ZB). Four pressure sensors are set on the center of each four sides of propeller guard. These sensors are used as switch for direct push operation and touch/auto operation, and they are connected to the A/D converter of second ArduPilotMega2.5 which is used as sequence controller (SC). Radio controller set (Futaba: T12FGH) is used for experimental operations. Aileron and elevator signals are introduced to SC. SC adjusts these signals according to the pressure sensor value and flight mode, and then it output them to FC. Other radio signals are directly connected to FC.

In this study, we present the results of both flight modes for air cargo system. The first flight mode is "Direct push operation", and the second flight mode is "Touch/Auto Operation".

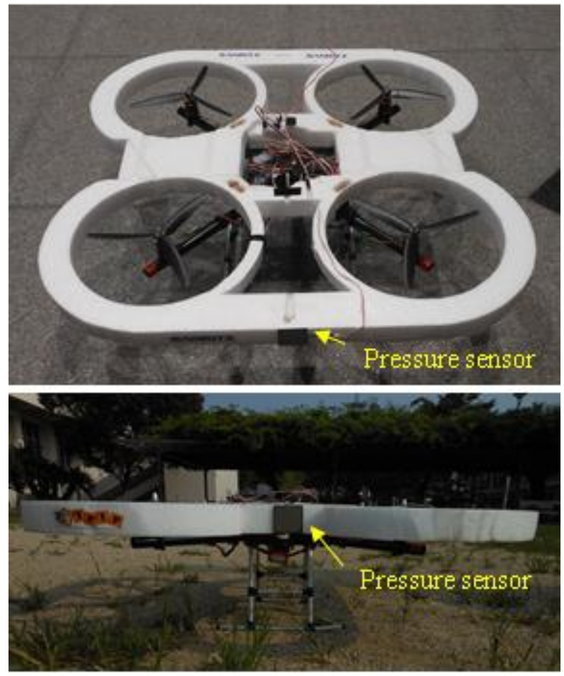

Figure 4 Test quad rotor helicopter

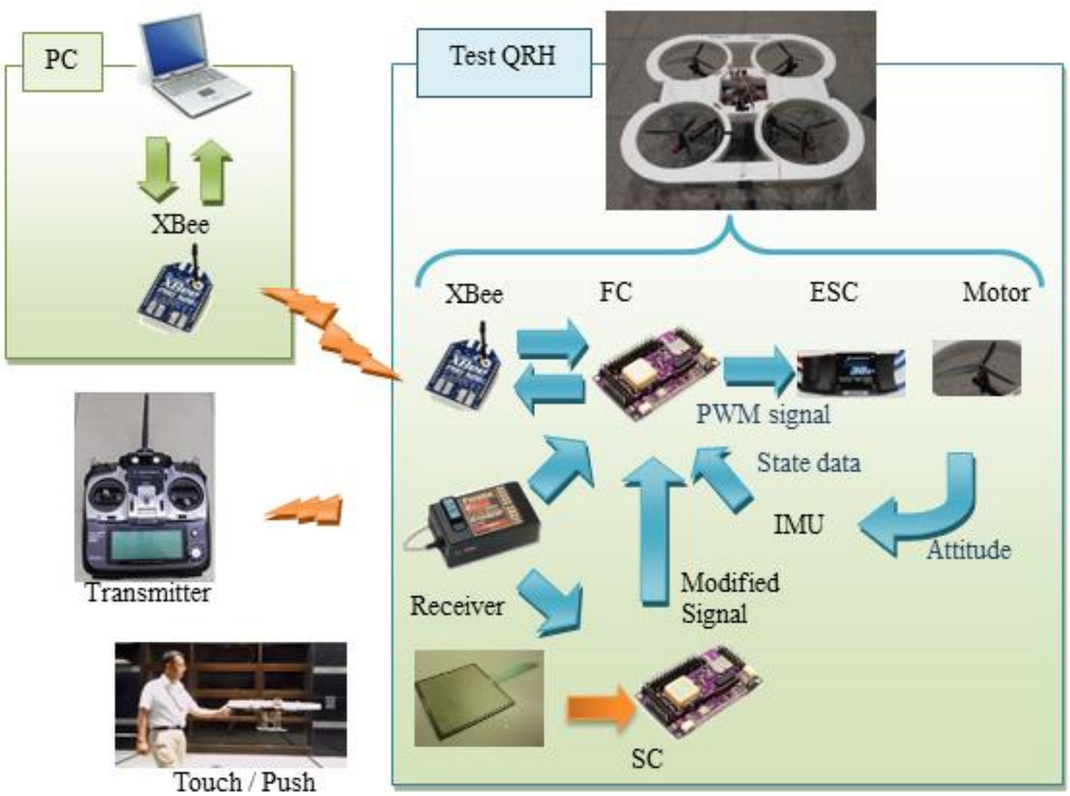

Figure 5 Experimental setup

III. Experiments and results

In this study, we present the results of both flight modes for air cargo system. The first flight mode is "Direct push operation", and the second flight mode is "Touch/Auto Operation".

A. *Direct Push Operation*

Figure 6 shows the scene of direct push operation. At first, test QRH is in "Loiter" mode (position control mode) of arducopter. When the operator pushes the pressure sensor on the propeller guard, SC detects input signal. If the input signal exceeds a certain threshold value, SC changes FC's flight mode to "Stabilize" mode (attitude control with altitude holding control) of arducopter, and send input signal to FC as related steering input. For example, the operator pushes the pressure sensor (PS) mounted on the back side of test QRH. The signal from PS is handled as elevator down input, i.e. test QRH starts to move forward.

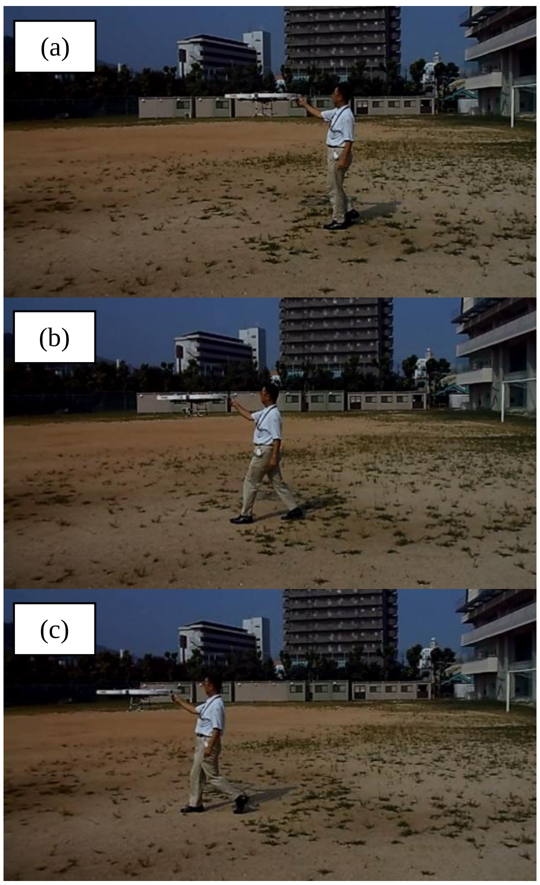

Figure 6 Direct push operation test

The size of elevator input is decided according to the value of PS - threshold value. When the operator stops pushing PS, the flight controller changes its mode to position control mode and starts to keep the current position. As the result, the operator moves the test QRH with small force. So this is a kind of power assisted operation.

B. *Touch/Auto Operation*

Figure 7 shows the second direct operation scene, touch/auto operation. In this scene, operator1 and operator2 tested this method. Also in this case, SC detects the input signal of pressure sensor. If the input signal exceeds a certain threshold value, SC changes FC's flight mode to "Stabilize" mode, and handles the input signal as related steering input, and keeps preset output value for 1.5 seconds duration as auto cruise.

At first, test QRH is in loiter mode. When the operator1 pushed PS1 (pressure sensor set on back side of test QRH), the signal from PS1 was handled as elevator down input i.e. forward command, and then QRH started to move forward. The forward motion continued for 1.5 seconds duration. Next, SC sets FC's flight mode to Loiter mode to keep the current position in front of operator2. Then operator2 pushed PS2 (pressure sensor set on front side of test QRH), the signal from

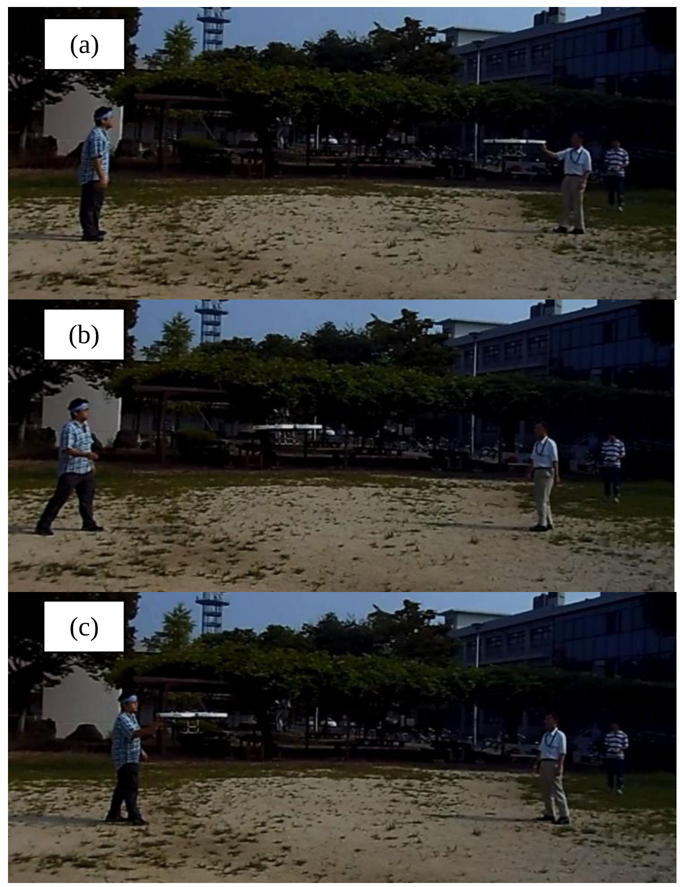

Figure 7 Touch/auto operation test

PS2 was handled as elevator up input i.e. backward command, and then QRH started to move backward. The backward motion continued for 1.5 seconds duration. After that, SC sets FC's flight mode to Loiter mode to keep the current position in front of operator1. These operations were continued.

Figure 8 shows the record of input signal of elevator from SC to FC during test operation of **Figure 7**. This figure shows that cyclic input on elevator by two operators. **Figure 9** and **Figure 10** show the trajectory of test QRH along forward/ backward and left/right direction during the test operation, respectively.

As shown in **Figure 8**, at 220 seconds, operator1 held test QRH by hand and move it to start position (-1.25,-2), then touched PS1for system check at 225 seconds. Then, operator1 started test operation. At 232.5 seconds, operator1 touch PS1 and SC changed flight mode to stabilize mode and adjusted elevator signal from 1520 μsec (neutral) to 1430 μsec (forward) over 0.5 seconds, kept 1430 μsec for 1.5 seconds, and returned to 1520 μsec over 0.5 seconds. At same time in **Figure 9**, test QRH shifted from (-1.25,-2) to (-5.4,-2). At 238 seconds, operator2 touch PS2 and APM2 changed elevator signal from 1520 μsec (neutral) to 1620 μsec (backward) over 0.5 seconds, kept 1620 μsec for 1.5 seconds, and returned to 1520 μsec over 0.5 seconds. At same time in **Figure 9**, test QRH shifted from (-5.4,-2) to (0.1,-2).

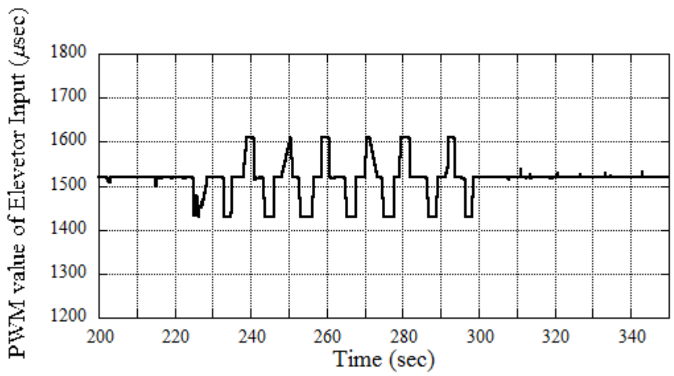

Figure 8 Elevator input signal during touch/auto operation test

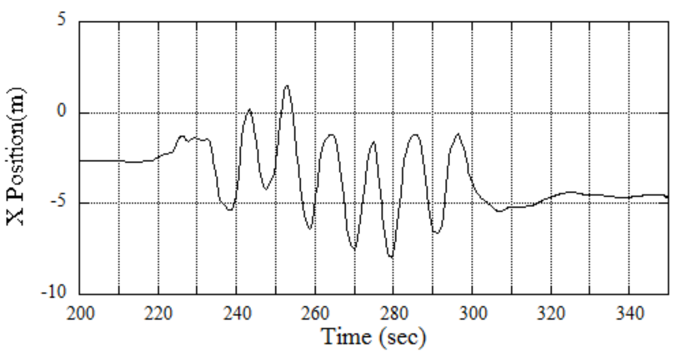

Figure 9 Forward/backward direction trajectory during touch/auto operation test

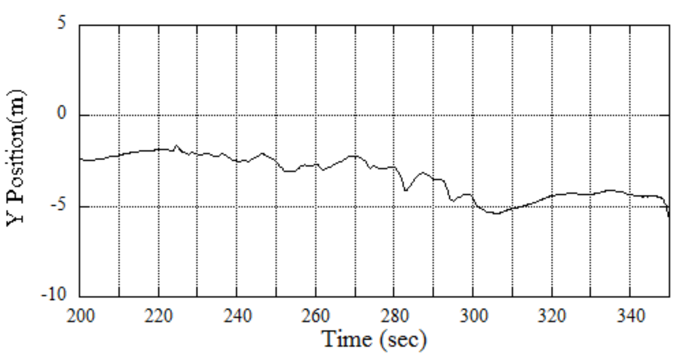

Figure 10 Left/right direction trajectory during touch/auto operation test

Figure 11 Test quad rotor helicopter with plastic bottle holder

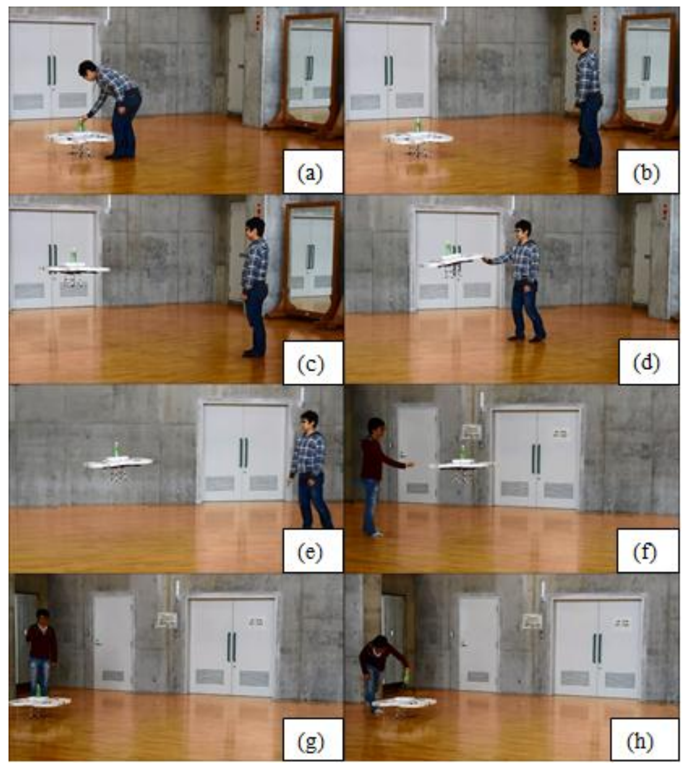

Figure 12 Scene of test transportation test

These are the one cycle of experiments. The shifting distance was about 5m, but it was affected by wind disturbance because flight mode was stabilizing mode during auto cruise, and position control was not done. In **Figure 10**, Y position was well kept until 280 second. But, it began to decrease gradually. This is same reason that flight mode was stabilize mode.

C. Transport Experiment of PET Bottle

Next, we carried out transport experiment of PET bottle. PET bottle holder was attached to the fuselage. **Figure 11** shows the test airframe.

The sequence of PET bottles transport experiment follows as below.

1. Mount a PET bottle.
2. Wait for the start-up by pressing PS1 or PS2.
3. Test QRH takes off to about 1m height and is in standby state with "Loiter" mode.
4. Push PS1 or PS2 to run touch/auto operation.
5. Test QRH flies for a certain time (1.5 sec in this experiment).
6. Test QRH reaches to the vicinity of the destination point.
7. Landing.
8. Take the PET bottle.

In order to execute this sequence, we add arming feature to SC, "Auto" mode (auto take-off) and "Land" mode (auto landing) to FC.

SC will do arming motors at the first input of PS1 or PS2, and then set FC to "Auto" mode to take off. Next, SC set FC to "Loiter" mode for waiting 2nd input of PS1 or PS2.

Second input will run the Touch/auto operation, then SC set FC to "Land" mode for automatic landing

Figure 12 shows the scene of test flight. As shown in the figure, we succeeded to transport the PET bottle safely by test flying cargo system.

D. Air-Drop Test of Tethered PET Bottle

According to Tubakimoto in ref [5] (Tsukuba University, Japan), the survival rate of a rescue victim who fell into water increases if he waits for a rescue while floating with holding flotage such as tethered PET Bottle. Tether is used to pull the rescue victim.

In this rescue method, rescue is possible only to the extent that thrown PET bottles arrive. Therefore, in order to extend the PET bottle distance, we did air-drop test of tethered PET bottle with flying cargo system. The sequence of air-drop experiment follows as below.

1. Mount a PET bottle.
2. Wait for the start-up by pressing PS1 or PS2.
3. Test QRH takes off to about 1.5m height and is in standby state with "Loiter" mode.
4. Push PS1 to run touch/auto operation.
5. Test QRH flies for 10sec (in this experiment).
6. Move Test QRH to the vicinity of rescue point by manual positioning.
7. Drop the PET bottle and start auto-return.
8. Manual positioning for landing
9. Auto landing

Figure 13 shows the scene of test flight. As shown in the figure, we succeeded to drop the PET bottle by test flying cargo system.

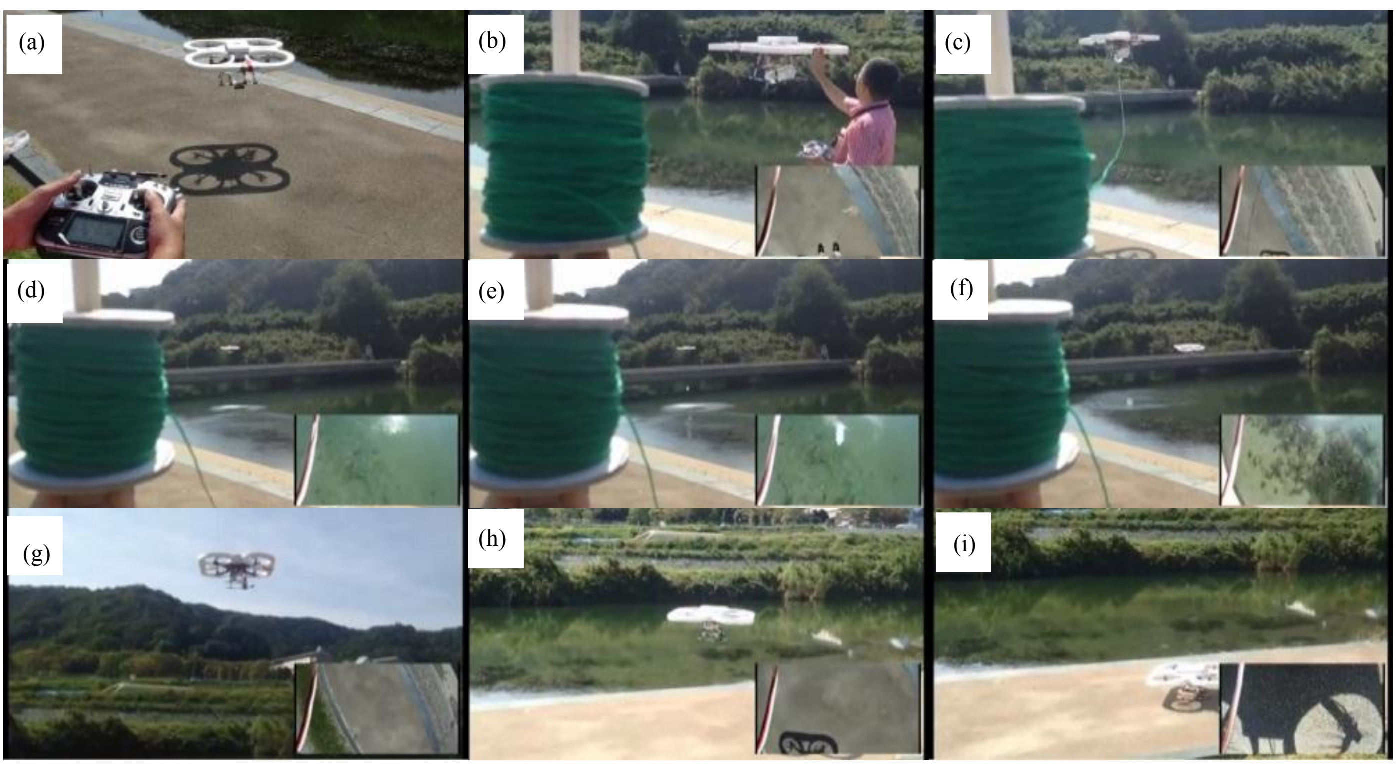

Figure 13 Scene of air-drop test of tethered PET bottle

IV. Conclusions

In this study, test QRH was well operated by using two direct touch operations. These direct touch operation method are effective to simplify QRH operation. But shifting trajectory of touch/auto operation is not controlled yet. So we will add trajectory control during auto cruise duration of touch/auto operation. Also we will evaluate the carrying capacity with load test.

Acknowledgment

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References

[1] Sonobe, M., Miwa, M. and Hino, J., Study on Simple Vibration Control for Small-Size Helicopter with Slung Load System (Experiment Based Studies of the Vibration Control on Hovering), Transactions of the Japan Society of Mechanical Engineers, Series C,Vol.78,No789, pp1460-1469 (2012). CrossRef

[2] Shin, J., Fujiwara, D., Hazawa, K. and Nonami, K, Model Based Optimal Attitude and Positioning Control of Small-Scale Unmanned Helicopter, Tran. Of the Japan Society of Mechanical Engineers, Vol.70, No.697 (2004), C, pp.2631-2637.

[3] Suzuki, S., Nakazawa, D., Nonami, K. and Tawara, M., Attitude Control of Small Electric Helicopter by Using Quaternion Feedback, Journal of System Design and Dynamics, Vol.5, No.2 (2011), pp.231-247. CrossRef

[4] Miwa, M., Shiraishi, I., Matsushima, M. and Minami, K., Remote Control Support System for R/C Helicopter,ServiceRobotics and Mechatronics, (2010), pp.125-130, Springer-Verlag.

[5] http://youtu.be/qMpqfdjg88o (in Japanese)