Evaluating Suitable Flight Height and Camera Angle of a UAV for Identifying Number Plates of Motorbikes

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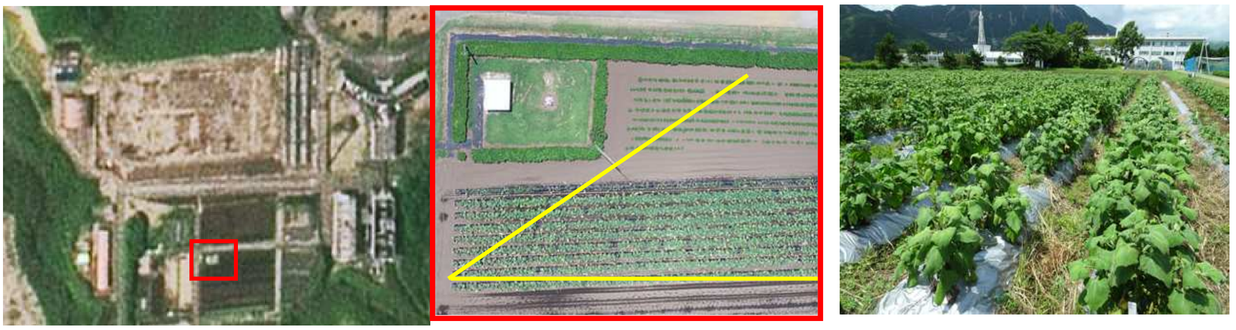
ABSTRACT: Due to the rapid advancement of the unmanned aerial vehicle (UAV) technologies, the ways of using UAVs, or drones, are expanding including the field of remote sensing. The authors have been using UAVs for connecting satellite images with in situ measurements. One of the interests for police to use UAVs for crime investigation. Under the cooperation with the Tokyo Metropolitan Police Department, the authors are investigating the suitable flight altitude of UAVs and the suitable view angle of the cameras onboard the UAVs for the purpose. In this study, the authors have used Zenmuse X3 camera attached on an Inspire-1 UAV of DJI for the investigation. In case of the above system, the flight altitude had to be lower than 7m for identifying the number of the motorbikes.

1. INTRODUCTION

In recent years, compact and inexpensive UAVs (Unmanned Arial Vehicle), popularly known as drones, are widely used for various observations in the field of remote sensing (Watts et al., 2012, Themistocleousa, 2014, Matese et al., 2015). By attaching compact camera or other sensors on a UAV, one can easily obtain high spatial resolution images of a local area. Especially, UAV is a strong tool to connect satellite remote sensing with ground observation (Cho et al., 2014). Figure 1 shows an example of comparing a satellite image, a UAV image and an on-site photo of a same area. The UAV image makes it easy to identify the ground features in the satellite image.

In Japan, the police are setting cameras in main places along the roads and taking pictures of the number plates of cars. The numbers are automatically identified and used for crime investigation. The system is called the Automatic Number Plate Recognition System (N system for short, 2018). The total number of cameras used in the N system was reported as 1690 in 2015. The N system usually take photos of the front number plates of cars. Since motorbikes have number plates only on the backside, the number plates of motorbikes are not the target of N system. Tokai University Research & Information Center (TRIC) has been cooperating years with Tokyo Metropolitan Police Department and the other prefectural police on training police officers for video image analysis. As one of the practices of the training, the authors have started to investigate the basic possibility of using UAV for identifying the motorbike license plate number for traffic related crime investigation.



(a)SPOT-2 image (2018/3/25) (b)UAV image (2018/8/27) (c) On-site photo (2018/8/27)

Yellow lines in Figure 1(b) shows the view angle of the on-site photo shown on Figure 1(c).

Figure 1. An example of comparing a satellite image, a UAV image and an on-site photo of the farm land of Aso Campus of Tokai University, Kumamoto Prefecture Japan.

2. OBSERVATION SYSTEM

In this study, Inspire-1 UAV and ZenmuseX camera of DJI were used for the experiment. The Figure 2 show the outlook of Inspire-1 and Zenmuse X. Table 1 and 2 show the specification of them.

(a) Inspire-1 (b) Zenmuse X

Figure 2. Outlook of the UAV system (DJI, 2018)

Table 1. Specifications of Inspire1 UAV

Weight	2845g (including propeller and battery)
Dimensions	438 x 451 x 301mm
Maximum speed	22m/s (ATTI mode, no wind)
Max service ceiling above sea level	4,500 m
Maximum wind speed resistance	10 m/s
Maximum flight time	18 min.
Operating Temperature	-10 to 40 deg.
Maximum takeoff weight	3,500 g

Table 2. Specifications of Zenmuse X3 camera

Maximum size	4000×3000 pixel
ISO Range	100- 1600 (Photo)
Electronic shutter speed	8 to 1/8000 seconds
Viewing angle	94 deg.
Sensor	CMOS 1/2.33"
lens	20 mm (equivalent to 35 mm format) , f / 2.8 Focus at ∞
Operating environment Temperature(℃)	0 to 40℃

3. TEST SITE

The athletic ground of Tokai University Shonan Campus located in Kanagawa Prefecture, Japan was selected for the test site. Figure 3 shows the location of the athletic ground in the Shonan Campus.

（Google map, ©2019CNES/Airbus etc.）

Figure 3. The location of the athletic ground in the Shonan Campus of Tokai University

4. Research method

4.1 Spatial Resolution Measurement

In order to identify the spatial resolution of the images taken by the Zenmuse X3 camera on board Inspire-1, a laboratory experiment was performed. Figure 4 shows the diagram of the experiment. The camera is placed on the floor and the photo of the wall was taken from 2m distance. Then, the pixel number of the wall width was calculated. Once the pixel size from 2m distance is calculated, one can easily calculated the spatial resolution R of UAV images taken at certain altitude H using the Zenmuse X3 camera.

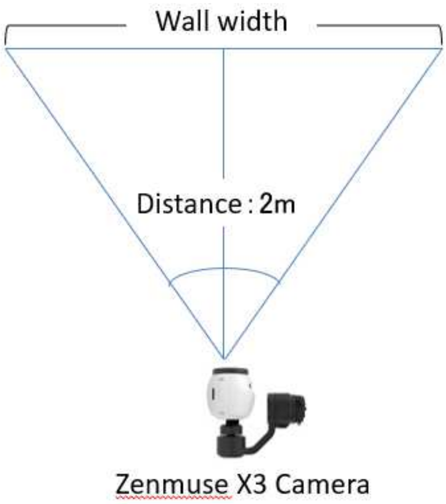


Figure 4. Laboratory experiment for identifying the spatial resolution of the Camera.

$$R = H \times W / 2N \qquad (1)$$

R: Resolution of the image taken from altitude H using the Zenmuse X3 camera (mm/pix)

H: Altitude of Inspire1 (m)

W: Wall width(mm)

N: Number of pixels corresponds to the wall width

In case of 1m altitude, the resolution R1 will be expressed in the following equation

$$R1 = W / 2N \qquad (1)'$$

By using equation (1) and (2), the relationship between the altitude of Inspire1 H and the resolution R of the image can be defined by the following equation.

$$R = H \times R1 \qquad (2)$$

4.2 Altitude Estimation Accuracy Evaluation

The altitude of Inspire-1 is estimated by the onboard GPS and displayed on a screen of the smart phone attached to the remote controller. The altitude estimation accuracy of Inspire1 was evaluated by performing the following procedure. The authors have prepared a 5m ruler and set on the ground to be captured in the images taken from the inspire-1. The images were taken at the altitudes starting from 10m to 150m with 10m interval. By counting the number of pixels L corresponds to the 5m ruler captured in the Inspire-1 image, one can calculate the spatial resolution of altitude of the Inspore1 which took the image as follows.

$$R = 5 / L \quad (3)$$

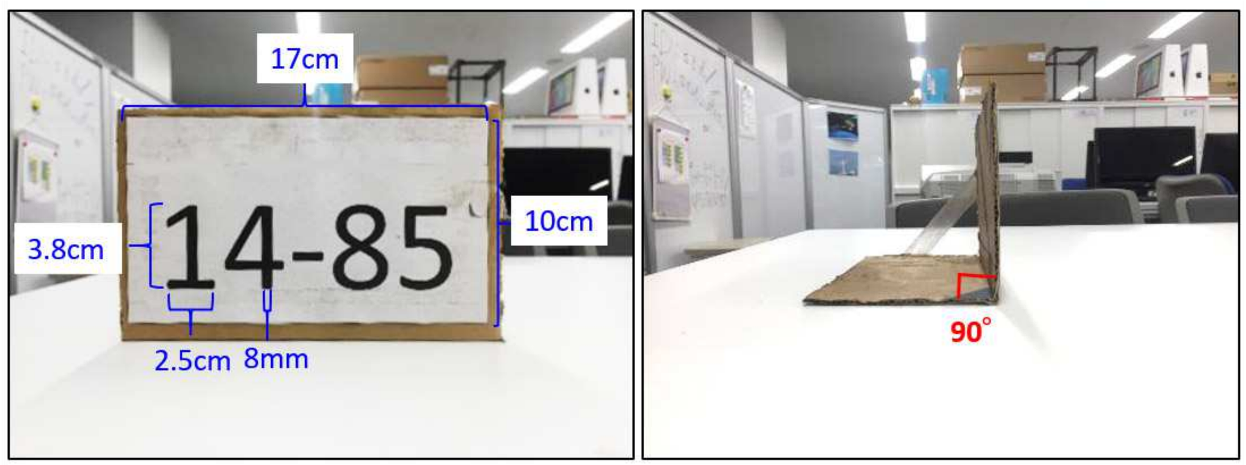
By using equation (2) and (3), the altitude H can be calculated by the following equation.

$$H = 5 / (L \times R1) \quad (4)$$

4.3 Number Plate Identification Experiment

In order to examine the possibility of identifying the motorbike license plate number using UAVs, the authors have performed an experiment in the following procedures.

(1) Production of imitations of a motorbike number plate
Firstly, a certain number of imitations of a motorbike number plate were produced using cardboard as shown on Figure 5.



(a) Front view **(b) Side view**

Figure 5. Produced imitation of a motorbike number plate

(2) Imaging from different altitude using Inspire-1
Figure 6 shows the conceptual diagram of the experiment. The imitated number plates were placed in line with 50cm interval from the nadir point. The imaging was performed by Zenmuse X3 camera onboard Inspire-1 with nadir viewing angle. The images were taken from 5 to 10m altitude with 1m interval. Figure 7 shows an image taken from 5m altitude.

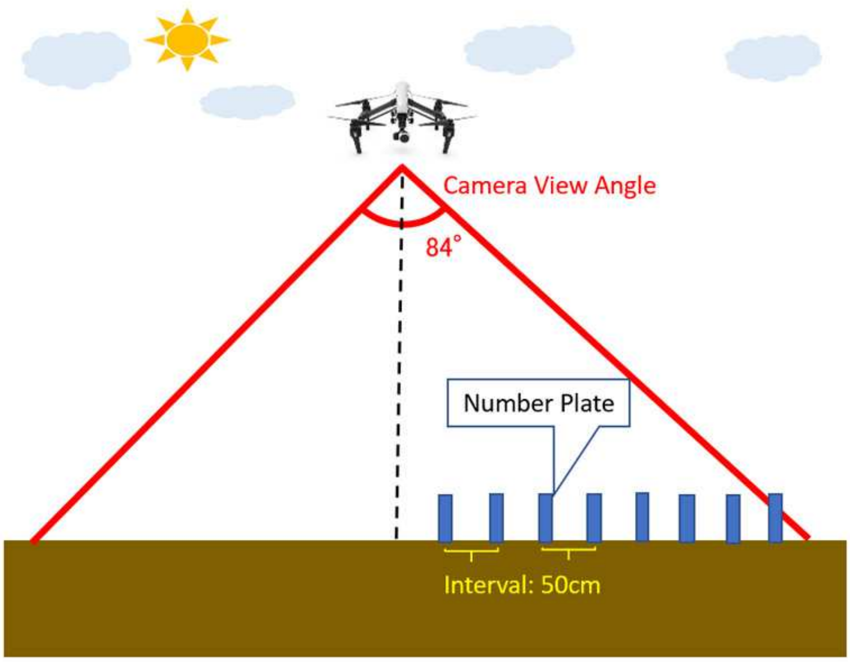


Figure 6. Conceptual diagram of the number plate identification experiment

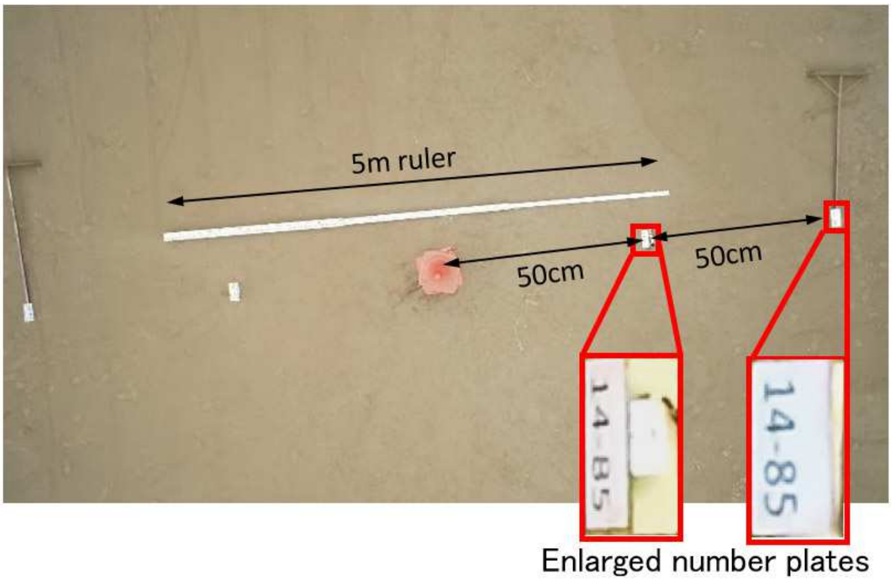


Figure 7. An image example taken from 5m altitude.

5. Results

5.1 Spatial Resolution Measurement

Actually, the spatial resolution measurement of Zenmuse X3 camera was performed in our previous study (Kojima et al., 2018). The camera was placed on the floor 2m distance from the wall of the room. Since the wall width was 3.621m and the number of the pixels of the wall width in the image was 4000 pixels, the spatial resolution of the image taken by the Zenmuse X3 camera from 1 m distance was calculated as the following using equation (1)'

$$R1 = W / 2N = 3621 / (2 \times 4000) = 0.455(mm/pixel) \qquad (5)$$

5.2 Altitude Estimation Accuracy Measurement

Figure 7 shows an image of the athletic ground including the 5m ruler. The images from the altitude starting from 10m to 100m with 10m interval were taken. Since the 5m ruler is captured in each image, by using the equation (4), the exact altitude of shooting each image was calculated. Figure 8 shows an example of the relationship between the altitude estimated by Inspire-1 and altitude calculated from each image. Usually, the altitude of a UAV is calculated using GPS and barometer. The square of the correlation coefficient of the altitudes estimated by Inspire-1 and calculated from images was 0.9996, which proved the reliability of the altitude estimated by Inspire-1. The altitude estimated using GPS and barometer could be more or less affected by the condition of ionosphere, weather etc. To evaluate the fluctuation of the altitude estimation accuracy of Inspire-1, the authors have performed the experiment for total of 16 days since last year. The gain and offset of the relationship between the two for each day are plotted on Figure 9. The average offset was 1.04m and the average gain was 0.935.

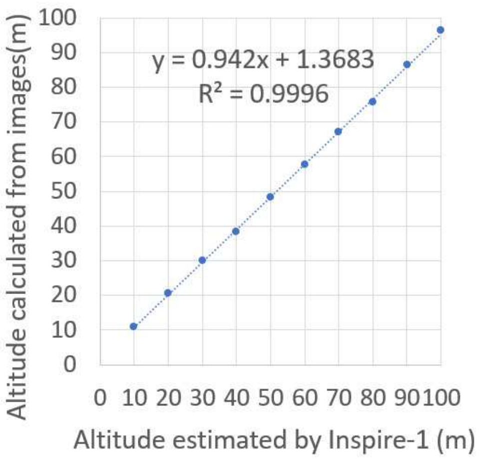


Figure 8. The relationship between the altitude estimated by Inspire-1 and the altitude calculated from each image taken at the altitude.

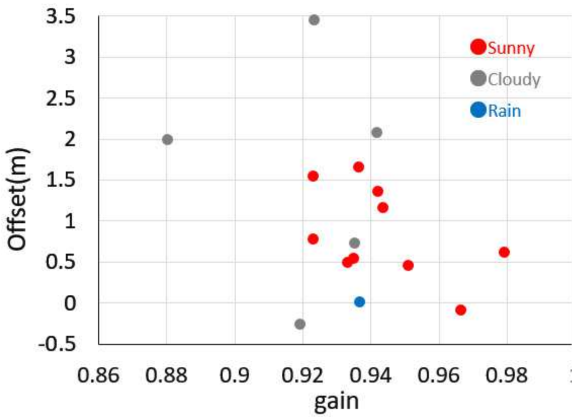


Figure 9. The relationship between the altitude estimated by Inspire-1 and the altitude calculated from each image taken by Zenmuse X3 onboard Inspire1.

5.3 Number Plate Identification

Figure 10 show the images of number plates extracted from the image taken at the altitude of 5m and the readability of those images. The incident angle shows the incident angle of the number plate from the camera. For an example, the incident angle of the number plate placed 50cm from the nadir point of Inspire-1 was 5 degree. In case of 5m altitude, the number of the plate was readable for the incident angle more than 16 degree. Since the incident angle of each number plate becomes narrower as the altitude of Inspire-1 goes high, the readable number plates reduces with the altitude. Also, the spatial resolution of images reduces as the observation altitude

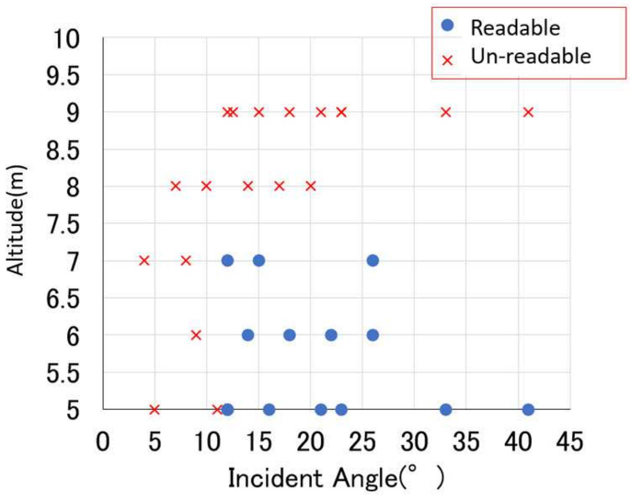
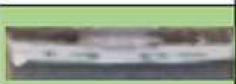
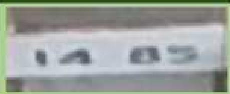


Figure 10. The relationship of altitude and incident angle to the number readability.

goes high. This also affected the readability of number plates. Figure 11 shows the relationship of altitude and incident angle to the number readability.

Altitude	Incident Angle	Image	Readability
5m	5°		×
	11°		×
	16°		○
	21°		○
	26°		○

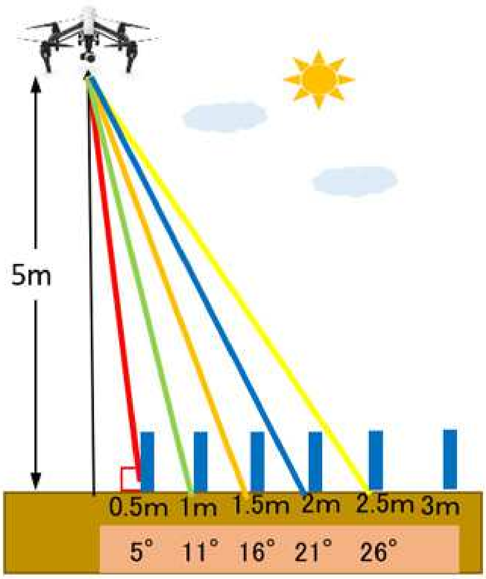


Figure 11. Number plate identification experiment result for the altitude of 5m.

The result show that the number plates of motorbikes are readable at altitude of 7m or lower with incident angle of 12 to 42 degrees. But, it should be noted that the incident angle of number plate becomes smaller as the altitude of UAV goes up. This means that location of readable number plate will gradually move far from nadir position as the observation altitude goes up.

6. CONCLUSION

In this study, firstly, the authors have investigated the altitude estimation accuracy of Inspire1 by comparing with the altitude calculated from the images taken at the same altitude. The square of the correlation coefficient of the two was around 0.996 which proved the high relative accuracy of the altitude estimated by Inspire-1 using GPS and barometer. On the other hand, the altitude estimated by Inspire-1 had average offset of 1.04m and the average gain of 0.935 against altitude calculated from images. The offset and gain changed from time to time. Further study is needed on this evaluation.

Secondly, the authors have investigated how the identification of the number plate of motorbikes in UAV images are affected by the altitude difference of the UAV. In our experiment, in order to read the number plate of motorbikes, the Zenmuse X3 camera onboard Inspire1 should fly lower than 7m with incident angle of 12 to 42 degree. However, it should be noted that the altitude condition discussed could change due to the specification of the camera onboard the UAV.

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REFERENCES

Watts, A.C., V. G. Ambrosia, E. A. Hinkley, 2012, Unmanned Aircraft Systems in Remote Sensing and Scientific Research: Classification and Considerations of Use, Remote Sens., Vol.4, pp.1671-1692.

Themistocleousa, K., 2014, The Use of UAV Platforms for Remote Sensing Applications:Case Studies In Cyprus, Proceedings of SPIE, The International Society for Optical Engineering, DOI: 10.1117/12.2069514.

Matese, A., P. Toscano, S. F. D. Gennaro, L. Genesio, F. P. Vaccari, J. Primicerio, C. Belli, A. Zaldei, R. Bianconi and B. Gioli, 2015, Intercomparison of UAV, Aircraft and Satellite Remote Sensing Platforms for Precision Viticulture, Remote Sens. Vol.7, pp.2971-2990.

Cho K., E. Baltsavias, F. Remondino, U. Soergel, H. Wakabayashi, 2014, RAPIDMAP Project for Disaster Monitoring, Proceedings of the 35th Asian Conference on Remote Sensing, OS-145, pp.1-6.

National Police Agency, Police of Japan, 2018, https://www.npa.go.jp/english/Police_of_Japan/Police_of_Japan_2018_full_text.pdf.

DJI, https://www.dji.com/jp, 2018.

Kojima, K., K. Naoki, K. Cho, 2018, A study on identifying number plates of cars and motor bikes using UAV, Proceedings of the 39th Asian Conference on Remote Sensing, Vol.5, pp. 3189-3194.