AUTOMATIC TARGET-IDENTIFICATION WITH THE COLOR-CODED-TARGETS

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Commission V, WG V/1

KEY WORDS: Targets, Colour, Identification, Software, Industry, Image, Three dimensional

ABSTRACT:

The 3 Dimensional Measuring System is a device to obtain the 3 dimensional coordinates of an object, using its numerous photo-images taken from different angles. This method basically requires the exact identification of the same corresponding points of all the obtained photo-images. But the more numerous are the images, the longer and harder it becomes if we depend on the manual work. To solve this problem we have developed colour-coded targets and a special algorithm with software, which automatically identifies the corresponding targets. We made careful experiments and verified its efficiency with the very satisfactory result.

1. INTRODUCTION

The 3 Dimensional Measuring System is a device to obtain the 3 dimensional coordinates of an object, using its numerous photo-images taken from different angles. In photo-image measurement we usually paste on the different parts of an object what we call “Retro-Refractive Target” in order to obtain highly accurate measurement often required in many industrial products (Kochi, N. et al., 2005). This round shining target refracts distinctly when photographed with a strobe flash or strong light.

However, the process to identify the targets is very complicated and often extremely time consuming. We must identify the same corresponding points on many different images taken in the successive pictures, especially when the pictures are taken from different angles and from all around the object or from 360° angles. Up to now we have done it by hand and laboriously identified the same target on different pictures by the specific number marked on each target.

The same holds true, when we have to measure a big object or a large area in segments, as the pictures and targets become so much more numerous. In fact, often we have to take more than 200 pictures with the number of retro target exceeding 3000. Besides, if the target identification is not correct, computer calculation goes nowhere and we waist a lot of time in searching the identification error.

To solve this problem, therefore, we have developed colour-coded target and related algorithm and succeeded to make the whole process of identification completely automatic.
So, in this report we should like to explain the color-coded target and the algorithm of automatic identification as well as the result of their verification experiments.

2. THE FUNDAMENTALS AND FLOW OF OUR 3 DIMENSIONAL MEASUREMENT SYSTEM

Our aim to have developed our new automatic color-coded target detection system was to enhance the efficiency of 3D image measurement by automatizing the target identification of 3D image measurement, which hitherto has been made by hand. We should like to explain the system along with the flow of the process operated by our software PI-3000, which we are developing for the target identification and 3dimensional measurement. Topcon 3D image measuring software, PI-3000, is a software which enables us to make both 3D measuring and modeling of a small as well as big object (a few centimeters to some 20 meters) and out of its result can calculate and produce the cross section, contour lines and the area measurement as well. And this, by using an ordinary digital camera and PC. And here we are basically applying Digital Photogrammetry and making 3D measurement by stereo method with two pictures on the right and left (Kochi, N. et al., 2003).

The Figure 1 is the flow of measurement:
(1) Before measuring (or even after photographing) we make camera calibration, using software PI-Calib (Noma, T. et al., 2002). This is a work to obtain analytically the camera’s principal point, principal distance, lens distortion by taking pictures of the control points allocated with high precision with a single camera from diverse angles.
(2) Next, we illuminate the object by a projector to mark on it random dots or patterns and take this picture with stereo cameras. If there are already some distinct design, the projection of patterns is not necessary. For latter kind of object we can do it by taking more than two overlapping pictures with one camera. And then we input the data of photographed images into the software and make target identification.
(3) Target identification is a process, in which we pick up or identify the point or position located at the same place on the pictures which are input in the PC, and mark or label them with specific name or number. With this identification the corresponding points of the pictures are determined and correlated.

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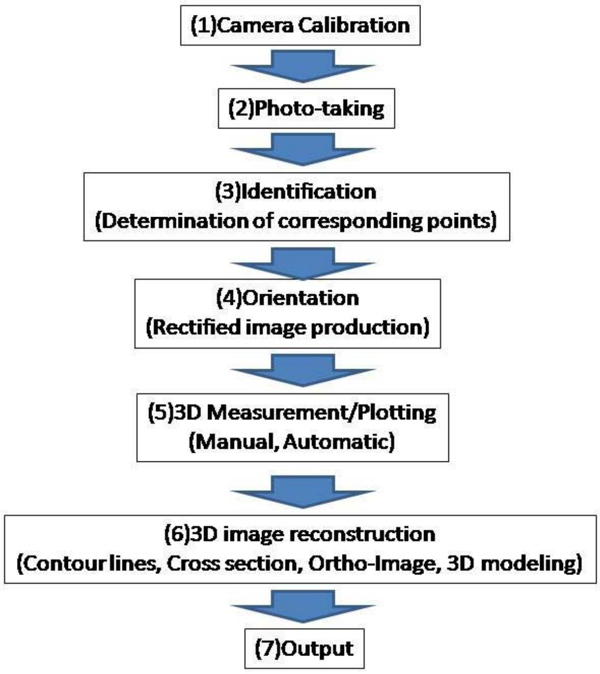


Figure 1. Flow of measurement

The automatic process we have developed is the process to make automatically the target identification (which used to be made by hand), using color-coded targets and automatic color-code targets detecting system. Thus, after Photo-taking (2)、we make identification (3) by the newly developed software (CC-Detector, automatic target-detecting software). And the work after the Orientation (4) is processed by another software PI-3000. In this way CC-Detector of the identification, can work as the separate software, much to the efficiency of the whole process

Up to now for target identification we opened more than one image simultaneously on the PC display and picked up or determined by hand the point located on the same corresponding position on the different images (Figure 2). However, we had a problem. The more images we put in, the less space was available for each picture with the less operability. Especially when the surface feature (necessary for identification) of an object is scarce and limited, often wrong place was mistakenly picked up as the corresponding position. And we lost a lot of time to find the mistake and rectify the situation. So, automatic identification was something highly demanded.

After choosing more than 6 correlated points on the two images of stereo-pair (right and left), we make orientation. Orientation is the calculation process to obtain the position of the camera and its inclination at the time of picture-taking. And from the parameter thus obtained we create the rectified image, and (5) from this cubic image 3D measurement and drawing become possible. In the automatic measurement of a surface it is possible to obtain in short time the 3D data as much as several thousands to several hundred thousands by simply determining the area. (6) And out of these data we can make Polygon and the texture mapping image pasted with the real picture, which enables us to view the reconstructed image from all angles.

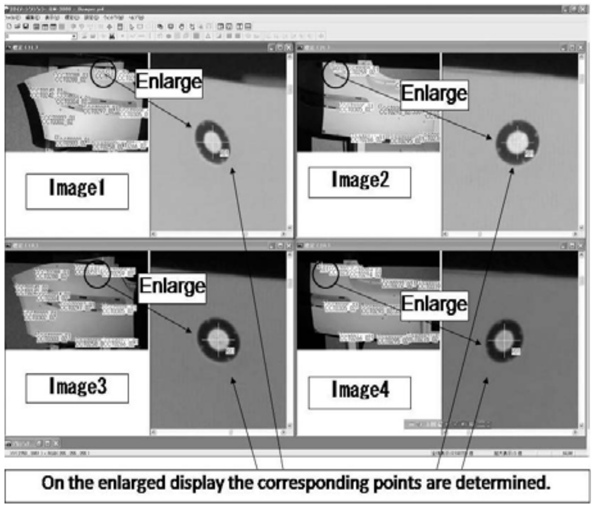


Figure 2. The display of manual identification with 4 images

(7) All these 3D data can be stored in the files of DXF, CSV, VRML and used for other purposes, such as creating plan drawing, rapid-prototyping, etc. And by feeding these data to the data-evaluating software by ICP algorithm (Besl, P.J. and McKay, N.D., 1992) for positions- identification and registration we can compare the result with the data of original planning, or compare the form before and after the change.

In the next chapter we will come to the subject of automatization of the target identification, which was made possible by color-coded targets and their automatic detecting system.

3. COLOR –CODED TARGETS

There are two kinds of coded target: centripetal type (Figure 3(a)) and dot-dispersing type (Figure 3(b)). These are already known and both of them were already reported (Heuvel, F.A., et al.,1992), (Hattori, S. et al.,2000), but the report on the color-coded target has been rare (Fraser, C.S. and Clonk, S., 2007).

However, centripetal and dot-dispersing types hitherto known have a problem. In order to make the targets recognized clearly, the targets are made to shine out or retro-act, while the object itself tends to be proportionally left in darkness and its texture remains obscure. This means, we can make accurate analysis only with dots, but not with texture.

Figure 3. Coded target (a) Centripetal type (b) Dots-dispersing type

In order to solve this problem, therefore, we have developed color-coded target, which enabled us to obtain even texture data, which means we can now measure on the surface. Besides, we can now not only obtain the data of the position of the points, but by simply increasing the number of the color, we can easily increase the number of the code.

As shown in Figure 4, our colour-coded target consists of a reflective retro-target in three corners and the color section where the position and combination of colors constitute the code.

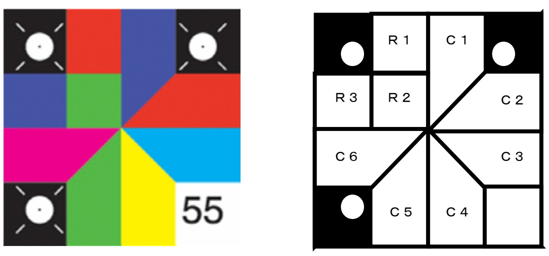
3.1 Color-coded Target's Specification

As shown in Figure 4, in the three corners of a square sheet there is a round white reflective part made of material which reflects back the light towards its source. The C1-C6 in Figure 4(b) is the color section for the code. The kinds of the color used for the code is six. Thus we could obtain 720 different combinations for the codes. Since the accuracy of the target identification demands to pick up the right label, on each target the same color should be used only in one place.

However, the condition of light, photo-taking and printing varies in each actual case and creates color shift. In order, therefore, to overcome the trouble of color shift we added the sections R1, R2, R3 (3 basic colors) to the target sheet 4(b) as a standard color reference or criterion parts. Thus by comparing the color in code-color section with these reference parts the correct identification of the color is always guaranteed and the color shift can be completely ignored.For the 6 colors, we used the six colors on the Hue-Circle, as in Figure 5. We chose Red, Green and Blue as the basic colors. The colors used for the color-code is the colors between these basic three, that is; Yellow, Cyan, Magenta, And in order to safeguard the color accuracy we added the basic colors to the code colors, thus making up six colors altogether. Again, in the lower right corner we reserved a section for numbering or visual code.

Detection of the Color-coded Target:
(1) First, the three round retro-reflective targets are detected to determine the area of the color-coded target.
(2) The colors are extracted into PC from color-code area and transformed into the code.
(3) Lastly, the color-code area obtained from reflective round targets and the code transformed from the color-code area are combined to make a specific label.

The detailed process of the automatic detection of the color-coded target will be explained in the next.



(a) (b)

R1～R3: Basic Color Section
C1～C6 Code Color Section

Figure 4. Color-coded Target

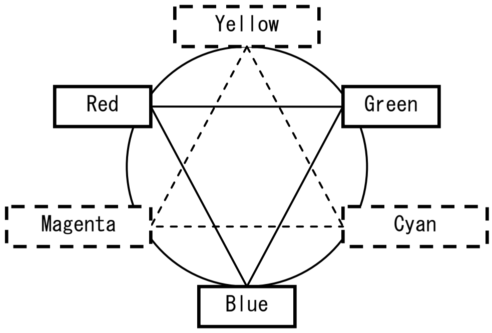


Figure 5. Basic Colors for reference and the Code Colors on the Hue-Circle

3.2 Automatic Detection of Color-coded Target

Figure 6 shows the flow of the algorithm of automatic detection of color-coded target.

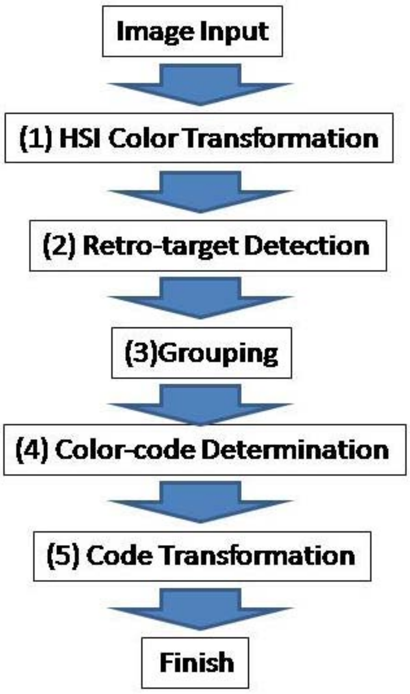


Figure 6. The flow of automatic color-code detection

The process is explained as in the flow:

(1) HSI Transformation is the process to transform the input images from RGB Color Space to Muncel Color System (HSI Color Space). Since HSI Color Space handles color in its Hue, Saturation and Intensity, the image processing is facilitated.
For HSI Transforming Model we have Hexago-conical Model, Twin Hexago-conical Model and Conical Model. For our work we used Conical Model, as Maeda and Murai advocates (Maeda, H. and Murai, S,1987).

(2) Retro-target detection comprises the process to find bright round marks out of the image by the element of "*I*" of the data obtained through HSI transformation (1) and the process to find its centre of gravity.

(3) Grouping is a process to determine the combination of the retro-targets which constitute a color-coded target. Based on the data of the centre of gravity as obtained in the previous process, we pick up three centres of gravity whose distance between each other (position) is close and group them together as one color-code.

(4) Color-code determination is a process to judge whether the area specified by the above grouping (3) is actually constituting a color-code.

This judgement is made by comparing the "*H* " element value of three parts (R1・R2・R3 in Figure 4(b)) in the basic color section to find out whether the proportion of "*H* " element value is correct or not. This is done by finding whether it satisfies the conditions or criterion as laid in the Equation (a).

$$\begin{aligned} &H_{R1} \le H_{R2} \le H_{R3} \\ &H_{R3} \le H_{R1} + 2\pi \end{aligned} \qquad \text{(a)}$$

Now we must proceed to find out whether the colors in the color section are rightly presented in Red, Green, Blue, Yellow, Cyan and Magenta and whether each color is used only in one place. This discernment is done by comparing the "*H* "element value of the color section with that of the basic color section, using the Equation (b) of condition-verification.

$$\begin{aligned} &H_{R1} - m \le \mathrm{Re}\,d \le H_{R1} + m \\ &H_{R2} - m \le Green \le H_{R2} + m \\ &H_{R3} - m \le Blue \le H_{R3} + m \\ &H_{R1} \le Yellow \le H_{R2} \\ &H_{R2} \le Cyan \le H_{R3} \\ &H_{R3} \le Magenda \le H_{R1} + 2\pi \end{aligned} \qquad \text{(b)}$$

where "m" is the constant for margin

If it was proved to be a valid color-code target, we proceed to the next step, but if not, we go back to the previous step of (3) and repeat the grouping process, reconfirming the centre of gravity.

The Code-transformation of (5) is the process to read code from the color-code section of the target. Here we first find the distribution feature of colors and then seek the similar pattern in the general table of all the features. Thus the color-code section is recognized as one of them and determined as a specific color-coded target. .

And we apply the same process (3)-(5) to all the centre of gravity data.

4. EXPERIMENT TO PROVE PRACTICAVILITY OF THE SYSTEM

We made three different experiments to test the accuracy of detection by our system of color-coded target and algorithm of its automatic detection. And also to find the influence of light source on the efficiency of detection we used different light sources.For 3D measurement we used our software PI-3000. The table 1 is the specification of PC used for the experiment.

CPU	Pentium 3.2GHz
Memory	3GB
OS	Windows XP Pro SP2

Table 1. Specification of PC

4.1 The Outdoor Experiment on a Car

We placed color-coded targets on a car (length 4.5m, width 1.7m, height 1.4m) and made all-round automatic measurement under the conditions specified in the table 2.
The Figure 7 shows how the photograph was taken.

Digital SLR Camera	Nikon D200
Lens	AF Nikkor 18mm F2.8D
Light	Sun beam + Strobe in camera
Object	Wagon Car
Image Size	3872 * 2592 (RGB Color)

Table 2. The conditions for photographing

Figure 7. Photographing Image

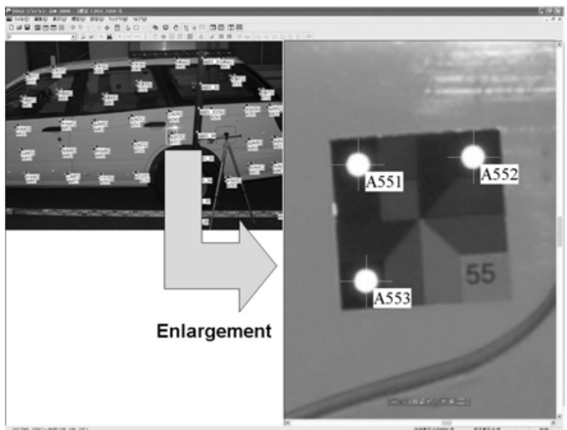


Figure 8. The result of color-code detection in outdoor environment

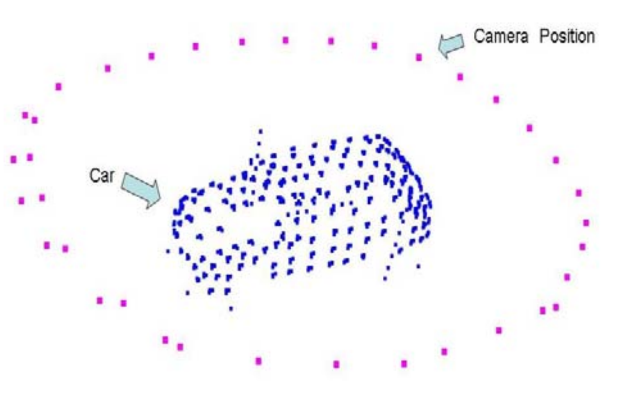


Figure 9. 3D measuring result of detected points and cameras position

The number of images or photos was 36, of which stereo-pairs were 32. The Figure 8 is the result of the target identification automatically detected. You can see three retro-targets labeled with a number.

As to the accuracy, the error of transformation in the color-code recognition or the error of wrong recognition of target in the place where it does not exist was none. The rate of false detection was 0.

Figure 9 shows the 3D measuring result of detected points and cameras position by PI-3000. The dots around the car are the photographing positions (36 points with 36 images). The photographing distance is about 2.5m.

We made accuracy assessment by measuring the distance between the 2 points of the retro-reflecting targets pasted on the scale bar. For this purpose, with the distance between 2 points measured by the instrument which can measure in 10 micron as the basic value we compared it with the result of our photograph measuring. As shown in the Figure 7, two kinds of scale bars were placed around the car, one for determining the scale and the other for assessing the accuracy of measurement. The result of our measurement was 899.90 mm, while that of the instrument was 899.82, which means the error rate was 0.08mm. This is good, enough to prove that our system is compatible for all-around 3D measurement under practical circumstances.

4.2 The Experiment on ground surface 20[m] x 5[m]

We spread color-coded targets on the ground surface of 20m x 5m and took the pictures under the condition specified in the Table 3. The number of image was 214 of which 194 were stereo-pair. The area of each photographing was about 1.5[m] x 1.5[m]. We moved photographing position each time about 0.5 [m] so that the pictures could overlap. Then we identified automatically the color-coded targets and calculated their 3D coordinates by PI-3000.

The result is Figure 10. White dots are the 3D position of the color-codes. There are 300 altogether. As to the time spent, by manual operation we spent about 6 hours, while we spent only one hour (or 16.7% of 6 hours) by automatic detection. We could detect all the 2049 color-coded targets. The rate of detection was 100% and the error was 0.

In order to investigate the effect of the change in sun beam strength, we took pictures from 17pm to 18pm, when the change was supposed to be great. But the detection rate was still 100%. This means we can detect the color-coded targets with satisfactory stability.Thus the system proved its applicability and practicality in large area measurement under ordinary environmental circumstances.

Digital SLR Camera	Nikon D200
Lens	AF Nikkor 18mm F2.8D
Light	Sun beam + Strobe in camera
Object	on the roof terrace
Image Size	3872 * 2592 (RGB Color)

Table 3. The Conditions for Photographing

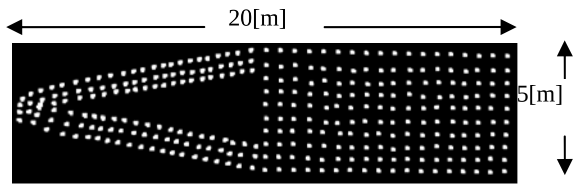


Figure 10. 3D coordinates position of the color-coded targets on the ground surface of 20 [m]×5[m]

4.3 Experiment on Car Bumper

We took pictures of a front-bumper in indoor situation under the conditions as specified in the table 4. We could make the identification process even with automatic detection alone. The rate of detection error was 0.

In this experiment we made measurement with surface in addition to the measurement with dots. We fed this data to PI-3000 and measured as 3D surface by its stereo-matching and created a model as shown in Figure 11.

Digital SLR Camera	Nikon D200 two cameras
Light Source	Projector hp mp3130 (DLP) 180 W-VIP lamp
Object	Front bumper of a car
Image Size	3872 * 2592 (RGB Color)

Table 4. The Conditions for photographing

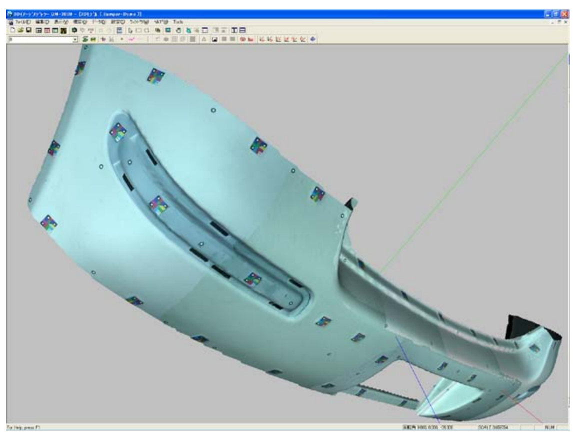


Figure 11. Result of Bumper modelling

The flow of the operation: First we photographed 28 images, of which 14 were the stereo-pair. (56 if we include the images with random-pattern). Second, using our newly developed software, CC-Detector, we made automatic identification of color-coded targets. Third, through PI-3000 we read the position-coordinates of the identified targets on the image and the label (or number) as well. Fourth, we connected models by relative orientation and bundle adjustment and made surface measurement by stereo-matching between each image. However, our work was much more simplified, because relative orientation and bundle adjustment needed only calculative work, as the targets had already been automatically identified.Thus, our system proved its applicability and practicality also in the measurement of indoor object..

5. CONCLUSION

In this presentation we explained our newly developed color-coded target and the algorithm of automatic detection of the target. And using them we made experiment to test the automatic operation and practicability of the system. The result was satisfactory and we could confirm the practical efficiency of color-coded target.

In future, other than the color-coded target, we should like to work on the development of detection algorithm for retro-targets without code. And also we should like to develop the scale bar with the principle of color-coded target.

REFERENCES

Kochi, N., Yamada, M., Watanabe, H., and Aoki, Y., 2005, 3D-measuring-modeling-system based on digital camera and pc to be applied to the wide area of industrial measurement, *The International Society for Optical Engineering(SPIE) Conference on Optical Diagnostics,* Sandiego

Kochi, N., Ito, T., Noma. T., Otani, H., Nishimura, S., and Ito.J., 2003, PC-based 3D Image Measuring Station with digital camera an example of its actual application on a historical ruin, *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XXXIV, Part 5/W12, pp. 195-199.

Noma, T., Otani, H., Ito, T., Yamada, M. and Kochi. N., 2002, New system of digital camera calibration, *ISPRS Commission V Symposium*, pp.54-59

Besl, P.J. and McKay, N.D., 1992, A method for registration of 3D shapes, *IEEE Transaction on Pattern Analysis and Machine Intelligence*, 14(2), 239-256

Heuvel, F.A., Kroon, R.J.G., and Poole, R.S., 1992, Digital close-range photogrammetry using artificial targets, IAPRS, Vol.29, No.B5, Washington D.C., pp222-229

Hattori, S. et al., 2000, Design of coded targets and automated measurement procedures in industrial vision-metrology, *International Archives of Photogrammetry and Remote Sensing*, Amsterdam, Vol. XXXIII, WG V/1

Fraser, C.S. and Clonk, S., 2007, Automated close-range photogrammetry: accommodation of non-controlled measurement environments, *8th Conference on Optical 3-D Measurement Techniques*, Vol.1 Zurich, pp49-55

Maeda, H. and Murai, S., 1987, HSI Conversion and Application to Multi-Spectral Data, Journal of the Japan Society of Photogrammetry and Remote Sensing, Vol. 26, No. 3