

AUTOMATIC TARGET DETECTION FOR VISION METROLOGY WITH USING COLOURED TARGET

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ABSTRACT:

Monitoring the movement of the excavated slope beside of the highway is important works in order to prevent disaster, like a land slide, beforehand. For the purpose to measure the displacement of the slope, it is insufficient to measure few number of the target to catch displacement as a surface. Then, recently some research has been done to apply the technique of the close range photogrammetry method by the digital photograph to measure the excavated slope. But it costs too many time to presume the exterior orientation element of the camera and to mark the all target ID in thirty or more Pictures. The method of applying some target group so called 'Coded Target' like as patterned target placement had been examined, but found out the difficulty for applying to measure the slope. Then the solution of using coloured target and to detect of each of them by software had tried. After some experiment, to describe the image data in colour of HSV colour space is found good for colour recognition. The result of field test mentioned, it could be judged that the automatic processing by the coloured target was effective for the underexposure picture (50%) up to proper exposure picture, and it made possible to reduce the 90% of operational time for the work to estimate camera exterior orientation and to get all target position in each picture.

1. OVERVIEW

1.1 Back Ground

Monitoring the movement of the excavated slope beside of the highway is important works in order to prevent disaster, like a land slide, beforehand. For the purpose to measure the displacement of the slope, it is insufficient to measure few number of the target to catch displacement as a surface. It's necessary to measure many number of the target.

But, with using the measuring equipment to measure many number of the target, it would be consuming many times and man powers. Like the highway which the small curvature of curve is not allowed, the excavation range is getting wider and higher, and it might be difficult to measure them by this way. Then, recently some research has been done to apply the technique of the close range photogrammetry method by the digital photograph to measure the excavated slope.

1.2 Basic Sequence

Table 1 is an example of the time distribution of the procedure

	ITEMS	PROCESS	NOTE	Time(min)	RATE(%)
1	Take Picture	Take picture of target area	28 pics	60	26
2	Move to PC	Transfer image data to PC	Auto	20	9
3	Marking Target	Estimate External Orientation & Marking Targets	Manual	130	57
4	Calculation	Bundle adjust calculation	SemiAuto	10	4
5	Verification	Check abnormal value	Manual	5	2
6	Comparison	Compare to Previous analysis result	Manual	5	2

Table 1 Basic sequence of Slope monitoring (values are typical number)

which calculates the displacement of the slope by the technique of the close range photogrammetry method.

As shown in the chart, the task No3, calculating the exterior orientation element of the camera & marking the targets on each picture, which exceeds 50% in all jobs. If this part of the job is automated, it might be easy to presume to shortening the time to acquisition of the result from measurement

The sequence to presume the exterior orientation element of the camera and to mark the target ID in the each image by the software for measurement which had been developed is shown below.

- (1) Display an image taken in the field on PC monitor
- (2) Clicking 4 to 6 targets by mouse, and mark the target ID to each clicked target
- (3) Input rough value of the camera position, and calculate the camera exterior orientation parameters by single photo orientation method.

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- (4) By calculation of 2D projection with the camera exterior orientation parameters and rough 3D coordination value of each target, to obtain the estimated position of the targets on the image and be marked them on the image.
- (5) Check the mark on the image and if it's not on the correct position, to adjust it on the correct position.
- (6) Seek the gravity centre coordination of the density of each detected target on the image.
- (7) Save the result of calculation.

In these procedures, task (2) is to mark the target and set of its ID by man hand. It is not so complicated job, and it is not the case that it requires special technical skill. But there is no ID marked in the target itself on the picture, so it is necessary to presume ID of the target from the geographical feature around the picture and to input it.

If odd ID is input here, all of the result of task (3) or later tasks would not be correct, and it is necessary to check all data. But for skilful person, it might be boring jobs to attach the target ID for all picture, which should be done for 30 to 40 or more pictures, and a mental load for worker becomes large.

If the target ID can specify automatically by software, it possible to decrease of the number of monotonous work items, and also it is possible to improve the precision of job.

Task (3) to Task (7) is just sequential job, and it is relatively easy work to replace to the computer program.

2. TARGET RECOGNITION

2.1 Automatic detection of the Target ID

There are some approaches to calculate or to obtain the exterior orientation parameters,

- (a) Apply some target group so called 'Coded Target' like as patterned target placement for example QR-CODE (some kind of 2D Bar-Code) and to recognize of those distributions by software.
- (b) GPS or other location detecting equipment install into the camera to measure the position of the 3D coordination of the camera and to measure the direction angle (vertical rotation, horizontal rotation and axial rotation) to pass the procedure of (2) and (3) in previous chapter
- (c) Set the different coloured target in the survey area, and to detect of each target colour by software

Among these solutions, the solution of (b) completely ignores the portability of the close range photogrammetry method, and it is necessary to develop or to introduce the equipment and material which measures position and angles.

The solution (a) is already realized in previous research. e.g. Hattori et.al, 1999 For the typical close range photogrammetry method which uses the reflective target (known as retro target), it mentioned to apply to arrange the layout of target group in geometrical pattern to recognize of target ID.

But it is difficult to apply the outside field like monitoring of the slope, because it is impossible to keep reflectivity during the long period of time for the reflective target.

And for the case of using retro target, it is necessary to execute speed light photography. But for measurement of the slope beside of highway in service, it is inadequate to use electrical flash to avoid some accident of traffics.

It is worth considering that to applying of the solution (c).

Because the target of the white and black framed is used just by this reason at the site of monitoring slope instead of using the reflective target which is used mainly with close range photogrammetry method, concerning the colour conversion of the target, colouring to the target, it is easy to make the coloured target,

If also the coloured target is dealt with coordinate measurement, it is necessary to be verified whether the coloured target central detection is possible same as the white target. But, the coloured target is used as the input data for specifying the photographing position. It is not necessary for decrease of central detection precision to be considered.

If the technique which detects the coloured target is established, position and ID of the target are detected automatically without doing big modification in procedure itself of the current system.

2.2 Colour space of Image data

The picture which was captured by the digital camera usually is retained as combination of numerical value of three channel, these are called as RGB (also called as Three Primary Colour), and which is called as Bit map Image.

But there is a various method to describe colour by numerical value, and this declaring method is called the colour space.

Summary concerning the expression of RGB and HSV is shown below.

To comment on each expression of the colour spaces except for RGB and HSV is not a purpose of this paper. So if detail information of each colour space is needed, please refer to other text book about the colour space.

As for the RGB colour space, disassembling colour in 3 components of red, green and blue, it expresses the picture at the value which is obtained by digitalizing the respective strength. For example, by sticking each filter of RGB on the photo sensor cells (e.g. CCD: Charged Coupled Device),

RGB colour element value at the point, as means reflected light value, can be acquired as numerical information. Figure 1 shows typical filter distribution on colour CCD imaging device.



Fig. 1 Typical filter layout on CCD device

The CCD imaging device, which is used for the digital camera and the video camera, records the image data as output voltage value data from each CCD cell which is RGB (or CMY: complementary colours of RGB) colour filter had installed.

But, in case of the eye (or the brain) of the human, when looking at a coloured object, it might be impossible to feel or describe the constitution of each element of value of RGB. (e.g. Red=30, Green=60, Blue=20) And also, it might be impossible to imagine colour to add Red element value 30 to previous object.

This means, the colour space of RGB gives very good way to record to digital storage and/or to express method for machine. But it is complete different for sensuous expression in the human brain (or eye). And it is difficult to express some algorithm for the feature quantity detection within the colour space of RGB, also difficult to execute the verification of that result.

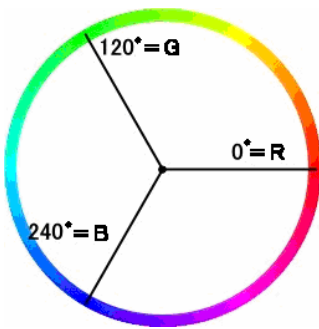


Fig. 2 Hue circle

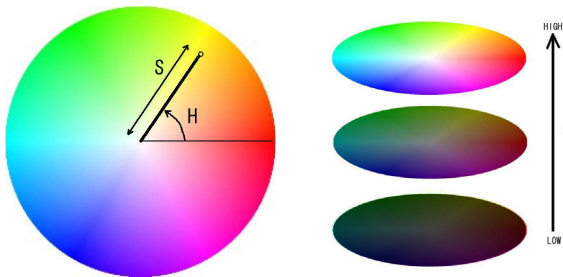


Fig. 3 H (Hue) and S (Saturation) Fig. 4 Definition of V

In the HSV colour space, colour is expressed with ternary value of H (Hue), S (Saturation), V (brightness Value). Figure 2 shows the hue circle. And figure 3 is the expansion of hue circle with saturation value. Figure 4 shows the difference of hue and saturation circle by changing V value.

According to Figure 4, H and S value is stable if V value changed. By this characteristic, with the picture which was photographed dimly and with the picture which was photographed clearly under the clear illumination, the object of the same colour means to have the same hue value.

However, when the light source changed in every exposure of photograph, hue value also changes with the spectrum of light source.

When the element value of S becomes high, depth of the colour (the vividness) becomes clear, when it becomes conversely low,

colour becomes faint colour tone. And if it becomes to zero, then the colour of the point will turn to grey scale.

In expression of the colour space of HSV, the ambiguous colour specification becomes possible to separate or to classify.

2.3 Conversion from RGB to HSV

The algorithm to convert the data from RGB to HSV is shown below equations,

< RGB to HSV >

$$V = \max (R, G, B) \tag{1}$$

$$S = (V - X) / V \tag{2}$$

where $X = \min(R, G, B)$

H gives different result in following 3 cases.

$$\text{case}(R=V) \quad H = (\pi/3) * (b - g) \tag{3a}$$

$$\text{case}(G=V) \quad H = (\pi/3) * (2 + r - b) \tag{3b}$$

$$\text{case}(B=V) \quad H = (\pi/3) * (4 + g - r) \tag{3c}$$

$$\text{where } r = (V - R) / (V - X)$$

$$g = (V - G) / (V - X)$$

$$b = (V - B) / (V - X)$$

range of value

$$[H: 0 - 2*\pi \quad S: 0 - 1 \quad V: 0 - 1 \quad R, G, B: 0 - 1]$$

Linear mapping conversion of the value of HSV and RGB is possible, and no other data for revise with the measurement value by another sensor, is required.

Because of this peculiarity, it makes possible like following conversion. At first to convert RGB Image to HSV, then revising the saturation value of data, and finally back conversion to RGB data, so the Image should be converted more fine coloured Image with keeping original RGB balance.

2.4 Typical Characteristic of HSV Colour Space

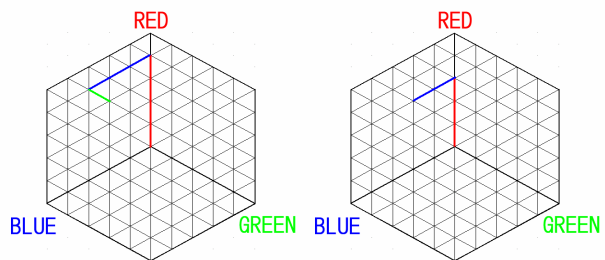


Fig. 5 Hexagonal Colour Space

When Hue and Saturation circle is deformed to a hexagonal shape of space, independent 3 axes, which are designated as the RGB axis, in isolated 120 degree each other is able to be defined (e.g. Figure 5). On this colour space, a colour value of R=4 digit, G=1 digit, B=3 digits (left part of Figure 5) and a colour value of R=3, G=0, B=2 (right part of Figure 5) are placed on the same point.

This means any colour of Hue and Saturation are able to describe in two value of RGB, and it's possible to describe in vector formula like as Equation (4). Also, this fact could be reach from Equation (2)

$$\text{RGB}(4,1,3) = \text{RGB}(3,0,2) + \text{RGB}(1,1,1) \quad (4)$$

So a colour of RGB(4,1,3) and a colour of RGB(3,0,2) have same Hue and Saturation value and different V value. Then it possible to be said they belong to the similar colour group by human sense.

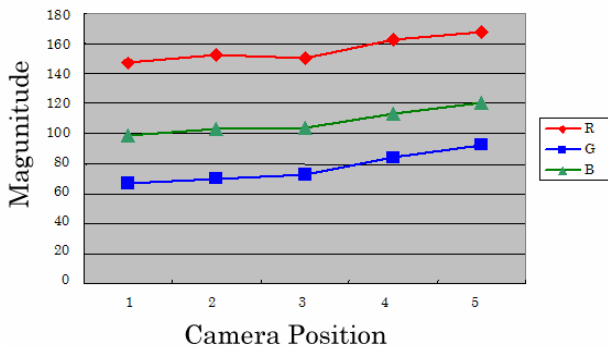


Fig. 6 Same Target (RED) element in RGB Colour Space from Different Camera Position

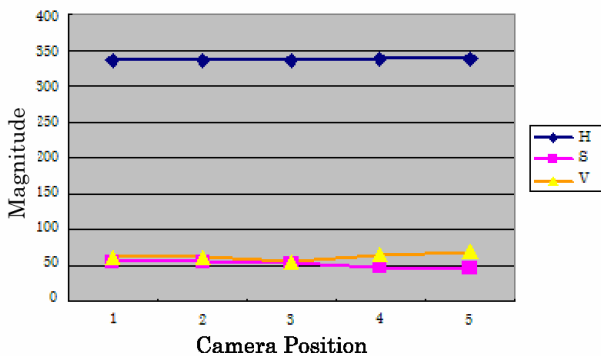


Fig. 7 Same Target (RED) element in HSV Colour Space from Different Camera Position

Figure 6 shows averaged element values in RGB colour space around of the RED target part in digital picture which taken at 5 different camera position in the real field. For the case of RGB colour space, it dose not show same value in 5 position. This means, if the target colour is same, element value in digital picture is not always same value in RGB colour space. And it might be depend on the environment when to take that picture.

Figure 7 shows same data in HSV colour space. According to this Figure, H (hue) value is very stable, and also, S (Saturation) value is almost flat. But V (brightness value) is sufficient differences to distinguish these. (Image at Position 4 and Position 5 is much brighter than others.)

By this feature, it is possible to detect a specified colour, which is described in HSV colour space, without depending on the change of photographing condition except for change of the light.

2.5 Applying to the Coloured Target

Picture 1 is a whole view of the test field. In the image it is possible to recognize the file different coloured targets. Picture 2 is image which expands the part of the coloured target. The colours are magenta, red, blue, cyan and green. With the picture of standard exposure the coloured target can be identified clearly with visual inspection.

The target of magenta and cyan are coloured with colour film for outdoor advertisement, and the target other is coloured with the colouration acrylic aluminium compound board. Before executing automatic processing, it is needed to click on each coloured target, and to set the central value of search colour, and then set ID of the nearest white target to notice the software which colour should be seek.



Picture 1 Image of the Test Field



Picture 2 Expand image of coloured target part

Verification of long-term durability is not done sufficiently concerning deterioration fading with the ultraviolet ray disclosure of the coloured target. . As for the coloured target because method of simple installation is adopted, when the colour fades, it is possible to be exchanged directly on site.

This system does not record the 3-D coordination of the coloured target. After finding the coloured target, the nearest white target with it is found. Therefore, the case where the coloured target is exchanged on site, it is not necessary to set to accurate position, and any skilful worker of installation is not required.

3. FIELD TEST RESULT

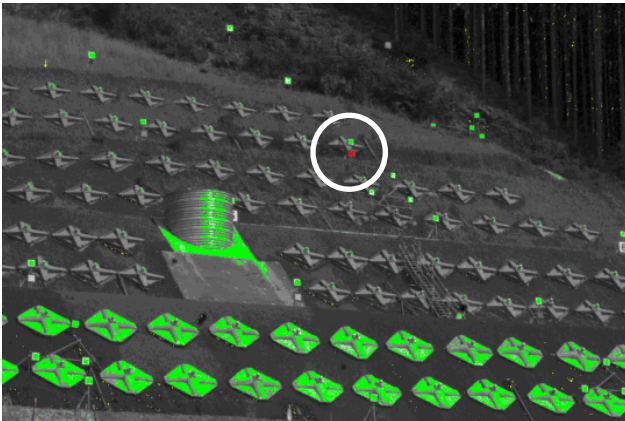
3.1 Automatic Detection

Picture 3 and Picture 4 are some result of automatic detection.

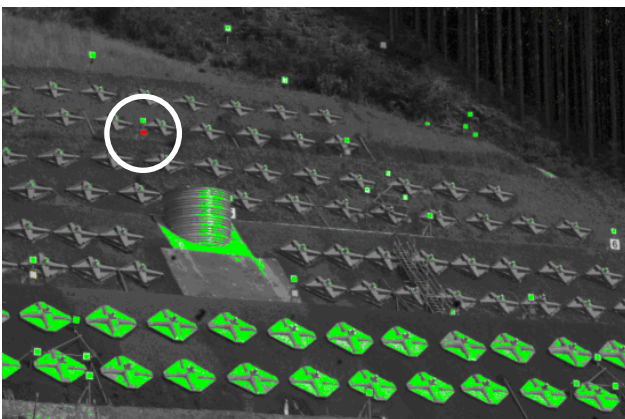
The part which is indicated with green colour shows the white target, or the concrete where the lightness is high with the achromatic colour.

With automatic detection processing, at first, the coloured target is detected. Then the white target which is closest to the coloured target which is detected is searched. Finally, picture coordinate of the central position (density centre of gravity) of the white target is calculated.

When there was two or more coloured target of same colour on the picture, automatic detection processing judges the detection result of the one which is close to the picture centre as correct ones. By this algorithm, when dividing the immense slope into plural blocks for measuring, automatic detection processing allows the fact that it is the plural same coloured target in the photographing range.



Picture 3 Result of automatic detection (RED Target)



Picture 4 Result of automatic detection (BLUE Target)

Picture 5 is some sample target image of very dark image captured in late evening time, and which automatic detection is not finished correctly.

In photographing at late in evening, lightness change for every picture exposure. It took 30 minutes to photographing from start

point to end point, and it was double time different of the lightness of surround. This shows, when sun altitude is low, it was verified that detection of the coloured target becomes difficult at the time of photographing in evening when luminous intensity changes moment by moment.



Picture 5 Expand image of coloured target in very dark Image

3.2 Field test results

Image No.	Normal Image			Dark Image			Very Dark Image		
	FOUND	RMSE	RES	FOUND	RMSE	RES	FOUND	RMSE	RES
1	5	0.017	□	4	0.001	□	5	0.003	□
2	4	0.029	□	4	0.003	□	5	0.002	□
3	5	0.016	□	5	0.004	□	5	0.002	□
4	4	0.037	□	4	0.003	□	5	0.003	□
5	5	0.011	□	4	0.002	□	5	0.010	□
6	4	0.037	□	4	0.001	□	5	0.005	□
7	5	0.008	□	4	0.005	□	5	0.026	□
8	4	0.044	□	4	0.006	□	5	0.102	□
9	5	0.010	□	5	0.003	□	3		×
10	4	0.047	□	5	0.002	□	2		×
11	5	0.012	□	5	0.002	□	4	0.020	□
12	4	0.053	□	5	0.003	□	4	0.023	□
13	5	0.024	□	4	0.006	□	3		×
14	4	0.050	□	4	0.002	□	4	0.023	□
15	5	0.030	□	4	0.003	□	4	4.836	×
16	4	0.056	□	5	0.001	□	3		×
17	5	0.012	□	5	0.001	□	1		×
18	4	0.062	□	5	0.002	□	0		×
19	5	0.006	□	5	0.004	□	3		×
20	4	0.054	□	5	0.004	□	3		×
21	5	0.006	□	4	0.001	□	2		×
22	5	0.004	□	4	0.002	□	2		×
23	5	0.011	□	4	0.013	□	3		×
24	5	0.014	□	3		×	2		×
25	5	0.021	□	4	0.001	□	4	0.012	□
26	5	0.016	□	5	0.002	□	3		×
27	5	0.023	□	4	0.007	□	5	0.030	□
28	5	0.027	□	4	0.005	□	5	0.033	□
	RATE	28/28	100%	RATE	27/28	96%	RATE	14/28	50%

Table 2 Field test result of three kind of photographing condition

Table 2 shows the result of three kind of exposure picture group to be operated for automatic processing to get exterior orientation parameters and all target position in the picture.

The result of executing automatic processing for the proper exposure picture, the underexposure picture (50%) and the

underexposure picture (33%) was 100%, 96% and 50% of achievement of each case.

From this result, it can be judged that the automatic processing by the coloured target is effective for the underexposure picture (50%) up to proper exposure picture.

4. CONCLUSION

Table 3 shows the result of improvement.

By the method to estimate camera exterior orientation and to get all target position in each picture by automatically with using coloured target, in past time it took 57% of whole jobs to mark targets, it could reduce to 12%. To consider as a single unit of job item efficiency, it was possible to achieve approximately 90% job time shortening. Also in the case which failed to detect all coloured target, it was possible to detect 2 to 3 targets.

Of this case, when the operator just marks 1 or 2 coloured target which could not be found by mouse, it is possible to make automatic processing execute.

By all of these results, it is confirmed that the description by HSV colour space is effective to detect the coloured target for applying the picture which captured at the out door field.

ITEMS	NOTE	Previous		Coloured Target	
		Time (min)	RATE (%)	Time (min)	RATE (%)
Take Picture	28 pics	60	26	60	53
Move to PC	Auto	20	9	20	18
Marking Target		130	57	14	12
Calculation	SemiAuto	10	4	10	9
Verification	Manual	5	2	5	4
Comparison	Manual	5	2	5	4

Table 3 Comparison of effectiveness by modification

As for detection of the coloured target, with photographing in usual day time, it was verified that it can execute at very high reliability. But when change of the lightness at photographing time is quick, for example at early morning time or at evening time close to sundown, it is unsuitable condition for coloured target detection.

There were one picture which was photographed at the evening (sun altitude low), and it indicated very different value from the picture from other photographing position, because it was in the special position where the camera received the direct reflection of solar light from the target surface.

Also the target surface was the glossy aspect, was the one of the serious reason which the original colour could not be acquired by the direct reflection of solar light. From this result, the material of the coloured target and the characteristics of the surface should be considered.

Furthermore, it was a considerable tendency that the green coloured target is little bit difficult to find in the dark image data to compare with other coloured targets. According to this result, as the reflecting material, the reflected light intensity of

green target is not sufficient for the purpose to detect green target in the dark image data.

In addition, long term verification is necessary about the colour fading of the coloured target influenced by the ultraviolet ray.

Lastly, if the whole process which reaches to analysis calculation from target orientation is automated, it must be seemed furthermore efficiency. But, in real filed, it must be not so special case that two or more targets are taken in over rapped each other or be hidden by other object, like some vegetation or mound or artificial structures. In which case, the application cannot recognize of these phenomena and marking the target point on the image, if the target not be able to be seen.

On this point, if the analysis computing had done with no verification of the result after the automatic operation orientating, after all place focus should be bad, and this means, it needed re-analysis and consuming the time. As for all processes in photogrammetry, the target position on the image is the only result of measurement value. And the accuracy of this result causes serious influence of the precision of computing, so the check work by the human is not possible to neglect.

5. REFERENCE

- [1] S.Hattori, K.Akimoto, A.Okamoto, H.Hasegawa and C.Fraser "The Design and Use of Coded Targets for Automatic Measurement with a CCD Camera", Proc.of ASPRS (American Society of Photogrammetry and Remote Sensing), Portland, May, pp.928-935. 1999
- [2] C. S. Fraser, S. Hattori, A. Okamoto, and N. Uno, "Vision-based dimensional inspection of freeway bridge blocks," International Archives of Photogrammetry and Remote Sensing, Vol. XXXII, Part5, Hakodate, pp.47-52, 1998
- [3] K. Akimoto, C. S. Fraser, H. Hasegawa, and S. Hattori, "Comparison of free network solutions by the artificial basis-based method with one by the generalized inverse in video metrology," International Archives of Photogrammetry and Remote Sensing, vol.XXXII, Part 5, Hakodate, pp.17-22, 1998
- [4] S. Hattori, and Y. Myint, "Automatic estimation of initial approximations of parameters for bundle adjustment," PE&RS, Vol.61, No.7, pp.909-915, 1995
- [5] C. S. Fraser, "Optimisation of precision in close-range photogrammetry," Photogrammetric Engineering and Remote Sensing, Vol.48, No.4, pp.561-570, 1992
- [6] H. A. Beyer, "Accurate calibration of CCD-cameras," Proc. of IEEE Computer Society Conference on Computer Vision and Pattern Recognition, pp.96-101, 1992