3D MODELLING AND VISUALIZATION OF CULTURAL HERITAGE USING MOBILE PHONE CAMERAS

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ABSTRACT:

Mobile Phone cameras which have 8 Mega Pixels have appeared on the market in Japan by NTT (docomo), KDDI (au) and SOFTBANK MOBILE (softbank). In these circumstances, convenient 3D measurement using mobile phone cameras are enormously expected in various close range photogrammetric fields.
With this motive, performance evaluations of mobile phone cameras are briefly discussed in this paper. Furthermore, in order to evaluate the effectiveness and practicability of mobile phone cameras for documentation of cultural heritage, 3D modelling and visualization of historical sculptures are investigated using mobile phone cameras.

1. INTRODUCTION

Recently, pixel numbers of consumer grade digital cameras are amazingly increasing, and there are many low-priced consumer grade digital cameras have appeared on the market in Japan. For example, 14.7 Mega consumer grade digital cameras have appeared on the market in August, 2008. On the other hand, it has been more receiving attention that mobile phones will become useful device for photogrammetric data acquisition since mobile phones have not only digital cameras but also GPS. The potential of 2 Mega pixels mobile phone cameras as a photogrammetric procedures and applications were examined (Armin et al., 2008). Resolutions of mobile phone cameras are drastically improving, however, mobile phone cameras which have 8 Mega pixels have already appeared on the market in November, 2008 by NTT (docomo), KDDI (au) and SOFTBANK MOBILE (softbank), and mobile phone cameras became the center of attention in close range photogrammetric fields. Figure 1 shows change of pixel numbers in consumer grade digital cameras and mobile phone cameras.

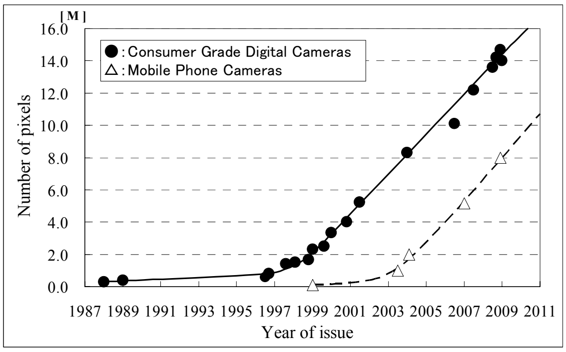


Figure 1. Change of pixel numbers in consumer grade digital cameras and mobile phone cameras.

Furthermore, developing low-cost photogrammetric system have ranked as one of the important issues during last decade in the ISPRS WG regarding Cultural Heritage; WG V/5 (World Cultural Heritage) for 1996-2000, WG V/4 (Image Analysis and Spatial Information Systems for Applications in Cultural Heritage) for 2000-2004, WG V/2 (Cultural Heritage Documentation) for 2004-2008, and WG V/2 (Development and promotion of low-cost, rapid, innovative, automated, commercial and open-source approaches) for 2008-.
With this motive, the authors have been taking notice of mobile phone cameras for realizing convenient photogrammetry. In order to evaluate the effectiveness and practicability of mobile phone cameras for documentation of cultural heritage, performance evaluations of mobile phone cameras are briefly discussed in this paper. Its application to 3D modelling and visualization of historical sculptures are demonstrated.

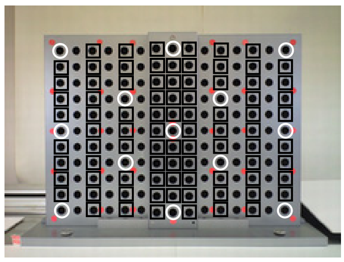
2. EXPERIMENT

2.1 Mobile Phone Cameras

In order to estimate accuracy of mobile phone cameras, experiments were performed using 16 kinds of mobile phone cameras. Table 1 shows the major components for these cameras.

2.2 Experimental Procedures

Figure 2 shows the test target (H : 640mm, W : 480mm, D : 20mm (3 rows in the center)) which was used in this paper. The white circled points are control points for camera calibration and another 86 black squared points are check points. 5 Stereo pairs for every camera were taken as base-height ratios 0.34 with changing altitude between 0.7-0.8m so that uniform photo scale be able to keep, and camera calibrations were performed by the bundle adjustment using 13 control points. After the camera calibration, accuracy was estimated using average RMSE for check points. The XY and Z accuracy of the center coordinates of each black circle points were produced with ±0.05mm, and these image coordinates were obtained as area gravity by image processing procedures.



◉ control points ▣ check points

Figure 2. Test target

Table 1. Specification of the mobile phone cameras

	F705i	W52S	P901i	P902i	W51SA	W53SA	W55SA	SH903i
Image sensor	CMOS	CMOS	CMOS	CMOS	CMOS	CMOS	CMOS	CCD
Image format (pixel x pixel)	1.3 M 1280 x 960	2.0 M 1600x1200	2.0 M 1600x1200	2.0 M 1600x1200	2.0 M 1600x1200	2.0 M 1600x1200	2.0 M 1600x1200	3.2 M 2048x1536
Image file size	0.35 M	0.37 M	0.63 M	0.55 M	0.48 M	0.43 M	0.55 M	0.85 M
Focal length	2.90 mm	3.80 mm	4.70 mm	3.70 mm	4.77 mm	4.77 mm	4.77 mm	5.60 mm
	D903i	SO903i	SH905i	P906i	W53CA	921P	W63CA	SH03-A
Image sensor	CCD	CMOS	CMOS	CMOS	CMOS	CMOS	CMOS	CCD
Image format (pixel x pixel)	3.2 M 2048x1536	3.2 M 2048x1536	3.2 M 2048x1536	5.0 M 2592x1944	5.0 M 2560x1920	5.0 M 2592x1944	8.0 M 3264x2448	8.0 M 3264x2448
Image file size	0.69 M	0.75 M	0.74 M	0.93 M	1.85 M	0.95 M	2.95 M	2.16 M
Focal length	3.48 mm	5.18 mm	4.10 mm	4.80 mm	5.20 mm	4.80 mm	4.60 mm	4.80 mm

2.3 Scale Factor

In order to compute image coordinates for each circle point, pixel coordinates should be transformed into image coordinates using scale factor. Scale factor was generally computed using pixel numbers in a line on the display and sensor size which was given from manufacturer's specification. Nevertheless, it is impossible to obtain sensor size for mobile phone cameras even from manufacturer's specification nor Exif header. Scale factor is unavoidably estimated by following procedures;

Table 2. Sensor type and sensor size

Sensor Type	Aspect Ratio	Diagonal Length (mm)	Horizontal Length (mm)	Vertical Length (mm)
1"	4 : 3	16.00	12.80	9.60
1/1.7"	4 : 3	9.50	7.60	5.70
1/1.8"	4 : 3	8.89	7.11	5.33
1/2"	4 : 3	8.00	6.40	4.80
1/2.4"	4 : 3	7.66	6.10	4.58
1/2.5"	4 : 3	7.20	5.76	4.32
1/2.7"	4 : 3	6.64	5.31	4.00
1/3"	4 : 3	6.00	4.80	3.60
1/3.2"	4 : 3	5.68	4.49	3.42
1/3.6"	4 : 3	5.00	4.00	3.00
1/4"	4 : 3	4.50	3.60	2.70
1/5"	4 : 3	3.60	2.88	2.16

＋Compute sensor size using relationship between horizontal length in object space and the image length by following equation.

$$s = \frac{P_x}{P_L}\frac{f}{H} \cdot L \qquad (1)$$

where s = horizontal sensor size (mm)
P_x = pixel numbers in a line on the display (pixel)
L = horizontal length in the object space (mm)
P_L = image length (pixel)
H = altitude (mm)
f = focal length (mm)

＋Estimate sensor type such as 1/3 inch using the computed sensor size.

Table 2 shows sensor type and sensor size for various sensor. Then if sensor size s is computed as 4.92 (mm), sensor size is estimated from Table 2 as 4.80 x 3.60 (mm) compare with horizontal length. It must be noted that the sensor type of most of mobile phone cameras are 1/3 inch instead of consumer grade digital cameras are 1/2.5 inch.

＋Scale factor is estimated using the estimated sensor size and pixel numbers in a line on the display.

3. RESULTS

In order to compare with consumer grade digital cameras respect to accuracy, horizontal and vertical accuracy are plotted in figure 3. Figure 3 shows horizontal and vertical accuracy for consumer grade digital cameras and mobile phone cameras. Solid line and broken line show standard error for horizontal and vertical which are computed by equation (2) (Abdel-Aziz, 1982).

$$\sigma_{X0} = \sigma_{Y0} = \left(\frac{H}{f}\right)\sigma_p$$
$$\sigma_{Z0} = \sqrt{2} \cdot \left(\frac{H}{f}\right) \cdot \left(\frac{H}{B}\right)\sigma_p \qquad (2)$$

where $\sigma_{X0}, \sigma_{Y0}, \sigma_{Z0}$ = standard error
H = altitude
f = focal length
B = base line
σ_p = pointing accuracy (here is estimated 0.1 pixels)

It can be found considerable differences in accuracy for P906i (5M) and 921P (5M) instead of W53CA (5M) doesn't show any significant differences. Image quality for the both cameras shows quite poor due to missfocusing, block and mosquito noise. In particular, severe missfocusing and mosquito noise are found at the sensor edge. Therefore, it can be evaluated that the differences may be caused by image compression because file size P906i is 0.93M, 921P is 0.95M instead of W53CA is 1.85M, but it was not evident.

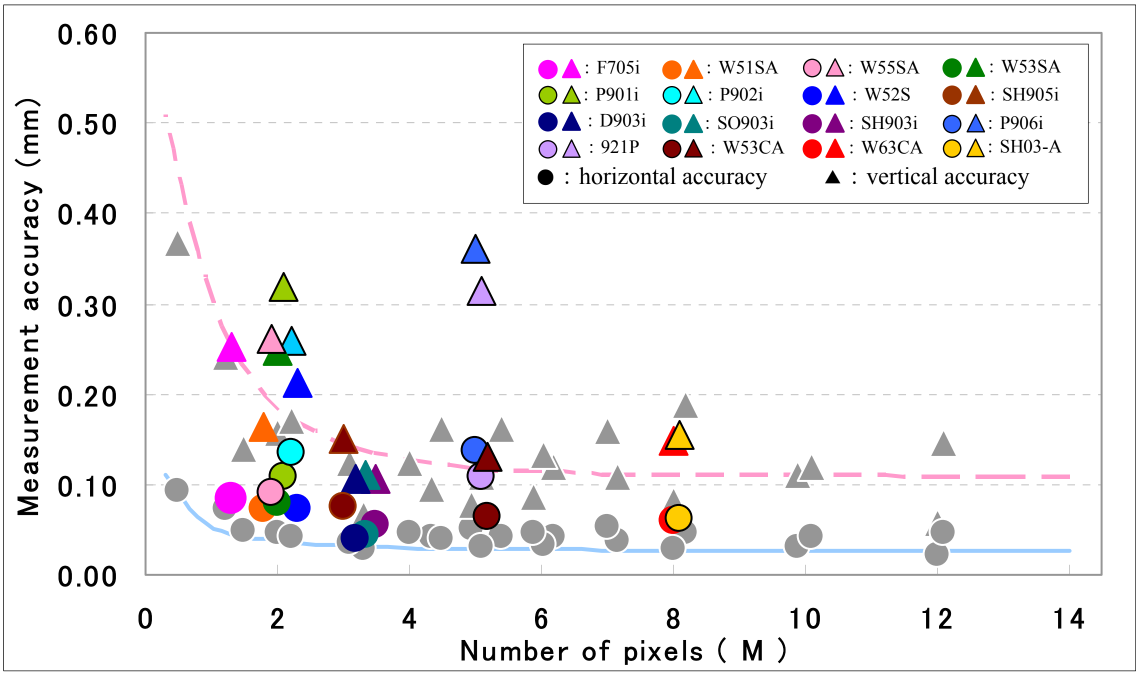


Figure 3. Horizontal and vertical accuracy

However, take into account that the standard errors were computed using 1/10 pointing accuracy, and current 8 Mega mobile phone cameras such as W63CA and SH03-A doesn't show any significant differences. Therefore, it is expected that mobile phone cameras will supply the place of a consumer grade digital cameras, and develop the market in digital photogrammetric fields.

4. ARCHAEOLOGICAL 3D MODELLING

There are many stone statues in Japan along the road, and existing stone statues were mostly produced at the Edo period (1603-1868). Stone statues show some figures based on regional faith, and it was told that stone statues were one of a road sign to pray for safety in travelling. Therefore, distribution of stone statues often gives us information for studying local history, customs and religion faith in those days.

In order to investigate an adaptability of the mobile phone cameras for documentation of cultural heritages, triplet images for stone statues were taken by SLR (Canon Eos20D 8Mpixels) and mobile phone camera (SH03-A 8Mpixels). Figure 4 shows an appearance of the stone statures which were taken by mobile phone camera. It must be noted that the head images were taken by the SLR with macro lens (Canon, EF100mm F2.8 MACRO USM, *f*: 100mm Fix).

4.1 Accuracy Check

After camera calibration for triplet images using the 3DiVision (Chikatsu et al, 2002, 2006), accuracy was compared using Thousand–armed Kannon. First row in figure 5 shows measurement values by laser range-finder (Leica, DISTO™ D3, ±1.0 mm). Second and third row show computed values using calibration results. But it must be noted that the second values were results for the SLR, and the third values were results for the mobile phone camera respectively.

It can be realized that the accuracy for the mobile phone camera show almost the same value compare with the SLR.

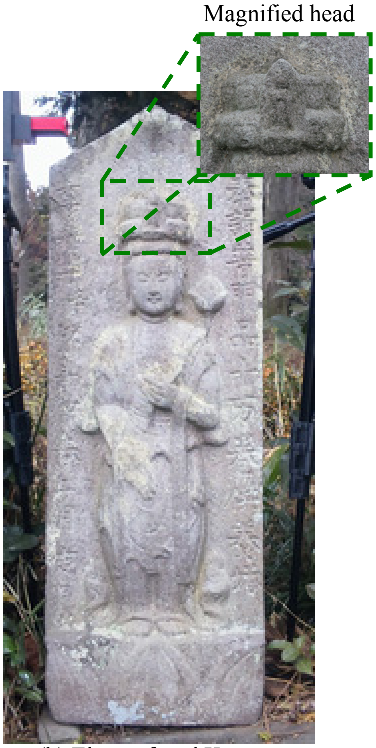
4.2 3D Modelling

Figure 6 shows contour image for each stone statue with 1.0 mm interval, and figure 7 shows 3D modelling. From these results, it can be said that mobile phone cameras will supply the place of a professional digital cameras, and develop the market in digital photogrammetric fields.

Figure 5. Absolute accuracy

(a) Thousand-armed Kannon

The stone statue is called thousand-armed Kannon because the statue has many hands with an eye on the palm to demonstrate her limitless saving ability.



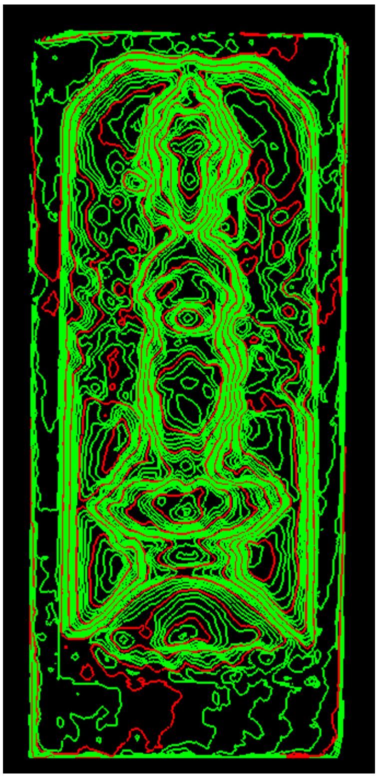
(b) Eleven-faced Kannon

The stone statue is called eleven-faced Kannon because the statue has eleven faces to present her pity for common people.

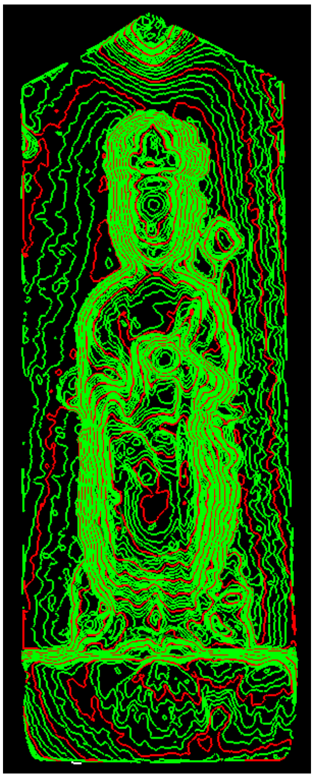
(c) Horse-headed Kannon

The stone statue is called horse-headed Kannon because horse-face was sculptured on the head to pray for safety in travelling.

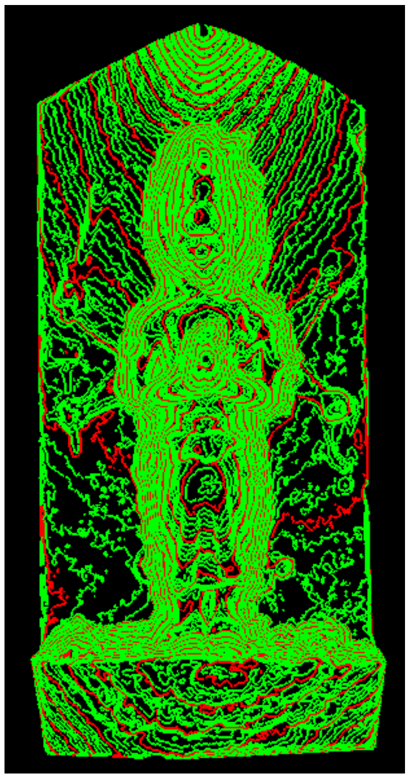
Figure 4. Stone statues



(a) Thousand-armed Kannon



(b) Eleven-faced Kannon



(c) Horse-headed Kannon

Figure 6. Contour images

(a) Thousand-armed Kannon (b) Eleven-faced Kannon (c) Horse-headed Kannon

Figure 7. 3D models

5. CONCLUSIONS

The effectiveness and practicability of mobile phone cameras for documentation of cultural heritage, 3D modelling and visualization of historical stone statues were investigated in this paper. In the first parts of this paper, it is verified that it can't find significant accuracy difference between current mobile phone cameras and consumer grade digital cameras.
Furthermore, the measurement values by the mobile phone camera show almost the same value compare with the SLR, and 3D modelling for stone statues was successfully demonstrated. Consequently, it is expected that current mobile phone cameras will supply the place of a consumer grade digital cameras, and develop the market in digital photogrammetric fields.

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