Generating 3D Model of "Meguro Residence" using Digital Armature Camera

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ABSTRACT:

Recently, the number of pixels of amateur digital cameras is amazingly increasing by modern semiconductor and digital technology. Nevertheless the highest pixel of amateur digital camera was 0.8 Mega pixel in 1996, the highest pixel was 5.24 Mega pixels in 2001 and 3 Mega pixel amateur digital cameras became the most popular camera on the market in Japan. In these circumstances, it is expected that high resolution amateur digital camera will become useful tool in various photogrammetric fields. In particular, developing low-cost photogrammetric system using armature digital camera is expected in archaeology and architecture field.

With this objective, the authors have been concentrating on developing a low-cost photogrammetric system using a digital amateur digital camera, and software for low-cost photogrammetric system was designed to perform convenient 3D measurements using amateur digital camera. Software was named "3DiVision" with key words: 3Dimension, Digital image and Visualization. 3DiVision will be introduced, and 3D modeling for the "Meguro residence" was investigated in this paper as an application of the 3DiVision in digital archaeological archive.

1. INTRODUCTION

When look back the history of CCD camera, "MAVICA" Magnetic Video Camera which was produced by Sony as a trial camera used CCD sensor should be noteworthy since the history of the CCD camera started from the MAVICA in 1981. Spending 5 years, RC-701 (Canon) was appeared on the market in 1986 as the first electric still camera in the world. Nevertheless 0.22 Mega pixels, this camera was for business use. From the view point of amateur digital still camera, MVC-C1 (Sony) which has 0.28 Mega pixels was the first amateur digital still camera, and the history of amateur digital camera started from the MVC-C1 in 1988. Furthermore, MDS-X (Fujix) was appeared on the market as the first amateur digital camera in 1989. Many amateur digital cameras were appeared on the market from 1988 to 1996, and the resolution was slowly increasing in these 8 years. In 1996, C-800L (Olympus) which has 0.86 Mega pixels received much attention as the highest pixels in the world, but the transmission techniques of image to PC was still issue. However, C1400-L (Olympus) achieved 1.41 Mega in 1997, and amazing acceleration of high resolution began from the 1998, and the current highest pixels 5.24 Mega was achieved by DiMAGE (Minolta) in 2001. As the results, there were many amateur digital cameras which have more than 3 Mega pixels on the market, and the functionary of transmission was standardized. Figure 1 shows evolution of number of pixels in amateur digital cameras.

In these circumstances, it is expected that the high resolution amateur digital cameras will become useful tool in various photogrammetric fields, e.g. industry, machine and robot vision, archeology, architecture, construction management, and so on. In particular, developing a low-cost photogrammetric system using armature digital camera is one of important issues for the ISPRS WG V/4 (Image Analysis and Spatial Information Systems for Applications in Cultural Heritage). Similarly, efficient construction of digital archives or virtual environments for structures of architectural significance and objects of importance to the World's cultural heritage have recently received more attention.

With this objective, the authors have been concentrating on performance evaluation of digital amateur digital camera (kunii, 2001(a)) and developing a low-cost photogrammetric system using a digital amateur digital camera (Kunii, 2001(b)). Software for low-cost photogrammetric system was designed to perform convenient 3D measurements using amateur digital camera (Chikatsu, 2002). Software was named "3DiVision" with key words; 3Dimension, Digital image and Visualization. 3DiVision will be introduced in this paper, and 3D modeling for the "Meguro residence" was investigated as an application of the 3DiVision in digital archaeological archive.

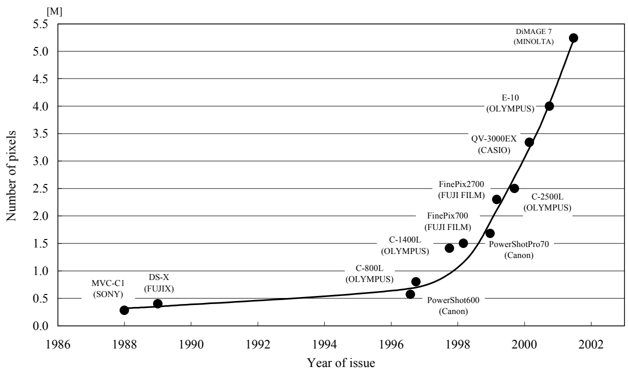


Figure 1. Evolution of number of pixels in amateur digital cameras

2. EVALUATION OF DIGITALCAMERA

In order to estimate accuracy of 3 Mega pixel amateur digital cameras, experiments for 10 kinds of amateur digital cameras and 2 kinds of professional digital cameras were performed using test targets by the authors (Kunii, 2001(a)). Table 1 shows the major components for these cameras.

Stereo images for every camera were taken so that the circle targets become equal size on the monitor, and image coordinates for 42 circle targets (9 circles are control points, 33 circles are check points) were given as a center of area gravity by image processing. Camera calibrations for each stereo image were performed by the bundle adjustment using 9 control points. After the calibration, lens distortion was evaluated using RMSE for the 33 check points, and it is concluded that lens distortion for the amateur digital cameras can be corrected sufficiently using radial polynomial 3rd degree model as usual (Fryer, 1986).

Furthermore, in order to investigate variation of accuracy by increment of resolution, relationship between number of pixels for each camera and RMSE for the check points which calculated using radial polynomial 3rd degree model were investigated. Figure 2 shows relationship between number of pixels and accuracy. It may be seen from Figure 2 that the accuracy for more than 3 Mega pixel digital cameras are hardly varied.

Consequently, it is expected that 3 Mega amateur digital cameras will supply the place of a professional digital cameras, and develop the market in digital photogrammetric fields.

3. 3DiVision

Generally, ground control points (GCP) are needed for camera calibration. However, surveying for the GCPs should be removed in convenient digital photogrammetry using amateur digital cameras. In order to resolve these issues, laser range finder (Leica, DISTO pro) was combined with amateur digital camera (CP-900Z) so that scale factor in relative orientation can obtain. Furthermore, • and •can be estimated as 0 degree as a advantage since the system is set on the leveling stand for theodolites (Kunii, 2001(b)). Figure 3 shows appearance of the low-cost photogrammetric system.

"3DiVision" under the key words; 3Dimension, Digital image and Visualization was designed to perform convenient 3D measurements using amateur digital camera (Chikatsu, 2002).

Table 1. Major components of the digital still cameras

		Manufacturer	Product Name	Number of Pixel ($\times 10^6$)	CCD Sensor	Image Interpolation Technology (Number of Pixel by Intrerpolation)
Consumer	(a)	Canon	IXY DIGITAL	2.11	1/2.7inch	
	(b)	EPSON	CP-900Z*	3.34	1/1.8inch	Hypict Technology (4.84Mega Pixel)
	(c)	FUJI FILM	FinePix 700	1.50	1/2inch	
	(d)	FUJI FILM	FinePix 4700Z	2.40	1/1.7inch	Honeycom Technology (4.32Mega Pixel)
	(e)	Konica	Q-M100V	1.00	1/3inch	
	(f)	OLYMPUS	C-2000ZOOM	2.11	1/2inch	
	(g)	OLYMPUS	C-3030ZOOM*	3.34	1/1.8inch	
	(h)	RICOH	DC-3	0.31	1/4inch	
	(i)	RICOH	RDC-7*	3.34	1/1.8inch	Image Enhancement Technology (7.07Mega Pixel)
	(j)	Victor	GC-X1*	3.34	1/1.8inch	Pixel Sift (6.00Mega Pixel)
Professional	(k)	FUJI FILM	FinePix S1 Pro	6.13	1.1inch	
	(l)	Kodak	DCS560	6.10	1.3inch	

* : Consumer digital still camera with more than 3million pixel sensor

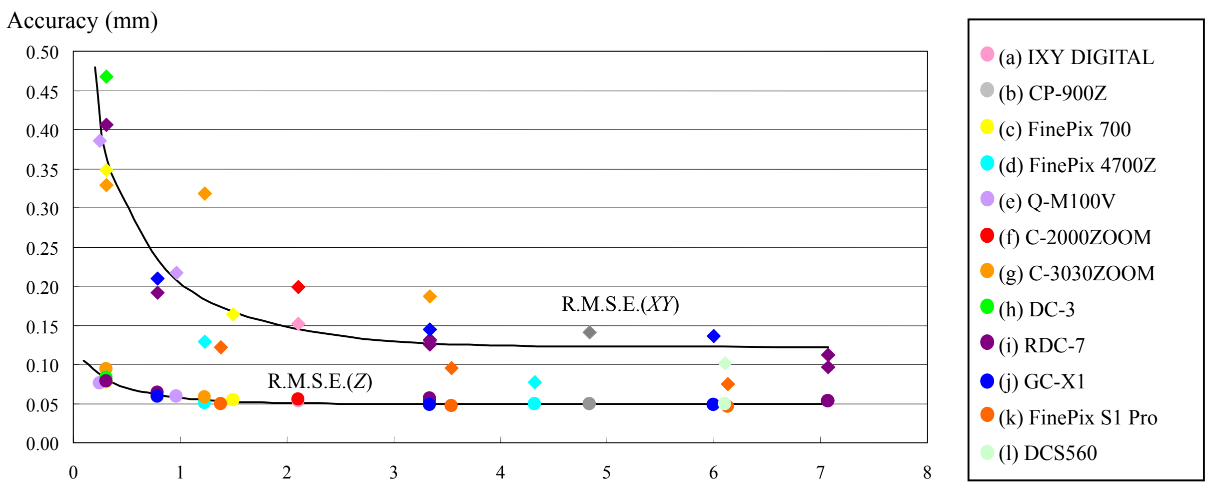


Figure 2. Evaluation Accuracy for Number of Pixels

The main algorithms of the 3DiVision is simultaneous adjustment using left and light image under combination with coplanarity condition and bundle adjustment, and 3DiVision have capability to perform orientation (interior, exterior) and 3D measurement for the following 3 cases in addition bundle adjustment using GCPs.

Case1: Altitude for left and right images are measured using the low-cost photogrammetric system, and original point and direction of X axis are given on the image.

Case2: Stereo image is taken using the photogrammetric system, but only distance of X axis is given on the image.

Case3: Conversion stereo image is taken without the system as the third case under the assumption that parallel stereo image often can't take. Distance in the object field is measured and original point and direction of X axis are given on the image. But, in order to control an influence of rotations, at least two height points are needed in the case 3.

Figure 3. Low-cost Photogrammetric System

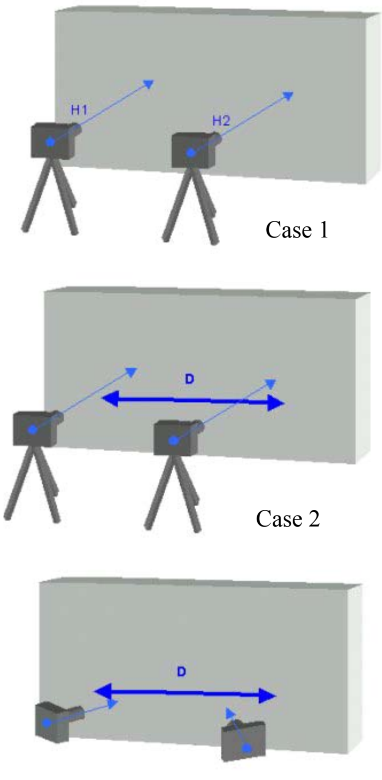


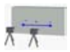
Figure 4. Imaging cases for the 3DiVision

Figure 4 shows the concept for the 3 cases. Actual 3D coordinates can be calculated via absolute orientation using altitude or distance after relative orientation using interior orientation parameters which were previously acquired with test model. Stereo image were taken with about 3m altitude, and accuracy for the 3 cases were estimated using RMSE for 42 black circle points on the test target. 3DiVision have additional function for getting high accuracy if height for a point on the X axis can be given.

Table 2 shows the RMSE for XY and Z coordinates for each case. Some differences can be found between the case1 and case2. Nevertheless, it can be said that the case 1 is useful and convenient in severe condition that can't touch on object. If it is possible to measure only a distance in object field, the case 2 is recommended for obtaining high accuracy than case 1. Furthermore, it can be seen that the accuracy for the case1 and 2 are improved by giving Z values for a point on the X axis.

Case 3 doesn't use the low-cost system, but height value for a point in the Y axis direction is needed more than height for a point on the X axis since • and •cannot be estimated as 0 degree. Free1, 2 and 3 in the case 3 means different stereo model, but each model shows higher accuracy compare with the other case. Accuracy for the each case are lower 2 or 3 times compare with the results of bundle adjustment, however, it is concluded that the 3DiVision is useful software for convenient digital Photogrammetry from the view point of restrict conditions.

Table 2 Accuracy of the imaging case

		Results of 3DiVision σ_{XY}(mm)	σ_Z(mm)	Resluts of Bundle 9GCPs σ_{XY}(mm)	σ_Z(mm)
Case 1 	Z:Not given	1.634	4.210	0.427	1.012
	Z:Given	1.783	2.812		
Case2 	Z:Not given	0.644	2.309	0.427	1.012
	Z:Given	0.923	2.480		
Case3 	Free1	0.656	1.120	0.400	0.580
	Free2	0.951	1.447	0.422	0.562
	Free3	0.803	1.661	0.407	0.464

4. 3D MODELING

4.1 Megro Residence

3D modeling for the "Megro residence" was investigated in this paper as one of applications of the 3DiVision. The Megro residence was constructed in 1797 (about 200 years ago). The house was the residence of "warimotoshoya" (headman of the villages in this area), and the main characteristic is the "chidorihafu" style in front roof window which was used as a chimney and added magnificence to the house. The house was designated as national important cultural assets in 1971. Figure 5 shows current Megro residence

Figure 5. Current Megro residence

4.2 Acquisition of 3D Data

Stereo images for the house were taken by the case 3 with wide angle lens, the detail procedure for 3D modeling are follows:

+ Feature points for relative orientation and 3D modeling were extracted automatically.
+ Corner points were corrected by canny operator.
+ Stereo matching was performed by area correlation.
+ Missmatching points were checked using backmatching.
+ Calibration was performed using scale distance.
+ 3D coordinates for extracted points were computed.
+ Successive orientation was performed.
+ Unification of coordinate system was performed.
+ Bundle adjustment were performed using deformated 3D coordinates.

Figure 6 shows extracted feature points which have 3D coordinates after model deformation.

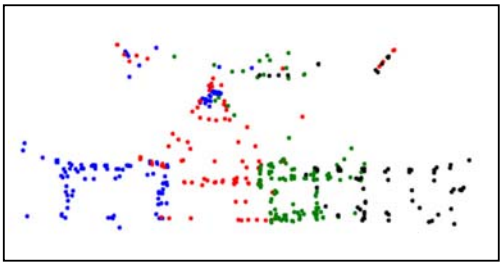


Figure 6. Extracted feature points

4.2 Wire Frame Model

Efficient 3D modeling system for the 3DiVision is still developing, however basic wire frame modeling are as follows;

+ Identify the faces of the house using Z coordinates.
+ Generate TIN for the each face using the feature points.
+ Extract outer lines for the each face in consideration of overlapped lines.
+ Eliminate inner points for the face.
+ Line extraction for the roof face was performed by manually.

Figure 7 shows the histogram for Z coordinates of the feature points and it can be estimated that the faces of the house exist around at 15.2m, 17m and 18m in the Z coordinate system. Figure 8 shows the wire frame model.

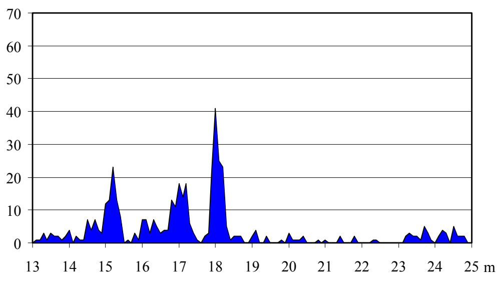


Figure 7. Histogram for Z coordinates

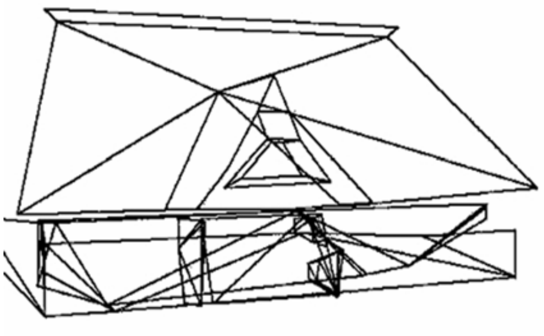


Figure 8 Wire frame model

5. LANDSCAPE ANIMATION

3DiVision have not ability for generating animation, nevertheless landscape, walk-through or fly-through animation for cultural heritage scene are often requested. For this goal, texture mapping and landscape animation for "Megro residence" were performed using CG software. Figure 8 shows one of landscape scene of animation.

Figure 9. Landscape scene

5. CONCLUSION AND FURTHER WORK

Archaeological application of the 3DiVision which was designed to perform convenient 3D measurements using amateur digital camera was investigated in this paper, and it is concluded that camera calibration was performed with only scale distance and 3D coordinates for the feature points were acquired automatically using image processing procedures. Although efficient 3D modeling system for 3DiVision is still developing, it can be said that automatic identification and construction of the faces which are important elements for the house modeling were achieved efficiently using information of the Z coordinates and the overlapped lines. Therefore, it is expected that 3DiVision will become convenient 3D measurements tool including 3D modeling in various photogrammetric fields.

However, full automatic generation of wire frame model and texture mapping are still issue as a further work.

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