

3D DIGITAL MODELING OF MODERN TIMES BUILDING FOR PRESERVATION AND RESTORATION

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Abstract:

This study aim is the establishing the 3D digital data of cultural architecture by applying the digital photogrammetric technique. I would applied as the basic data for preservation and restoration of cultural assets by suggesting the direction of establishing 3D digital data and the more accurate measurement methods than before lagged ones. And I could establish the useful data for visual analysis by connecting the ortho-image which was made by digital image for the object and the vector data which was acquired by plotting. The establishment of precise 3D information by photogrammetry was possible, so the application of photogrammetry for measuring various cultural assets which require precise measurement is expected actively in near future.

1. INTRODUCTION

Measuring cultural assets requires precise measurement data for preservation and restoration and also precise interpretation by non-contact method without damaging cultural assets. Recently measured data needs to be 3D digital data not existing 2D drawing data. These digital data can be used in extensive areas and be modified, supplemented and permanently preserved so that they are preferentially requested in preservation method planning for cultural assets. However, drawings prepared by existing measurement methods for cultural assets are not satisfactory in terms of accuracy and need additional works to convert drawings to digital data.

Thus, this study aims to examine applicability of digital photogrammetry by applying photogrammetric techniques and analyzing space in various ways using acquired digital data for more precise and effective acquisition of 3D digital data for cultural assets. To this end, the main building of Korea University, the large architecture designated and maintained as the historical relic's No. 285, was selected as the subject. Then, digital images of the subject have are obtained by accurate plan to take pictures so that digital data from digital images and reference point measurement performances required for 3D image interpretation will be generated. Moreover, 3D digital drawings on the front side of the subject are prepared using obtained digital data so that this study will suggest efficiency in digital photogrammetry in acquiring effective basic data for maintenance, management and restoration of large cultural assets. Furthermore, this study will present convenience of digital photogrammetry for restoration of cultural assets on the basis of dimensional digital data as generating still images from digital images and carrying out 3D modeling for the subject. Figure 1 illustrates the research process mentioned above.

Coordinates of reference points required for 3D image analysis were acquired using Mono Mobile 3-D Station and coordinates for reference points on different sides were obtained using the same coordinate system.

62 photography points were selected for analyzing all planes of an object and analysis planes were classified into 25

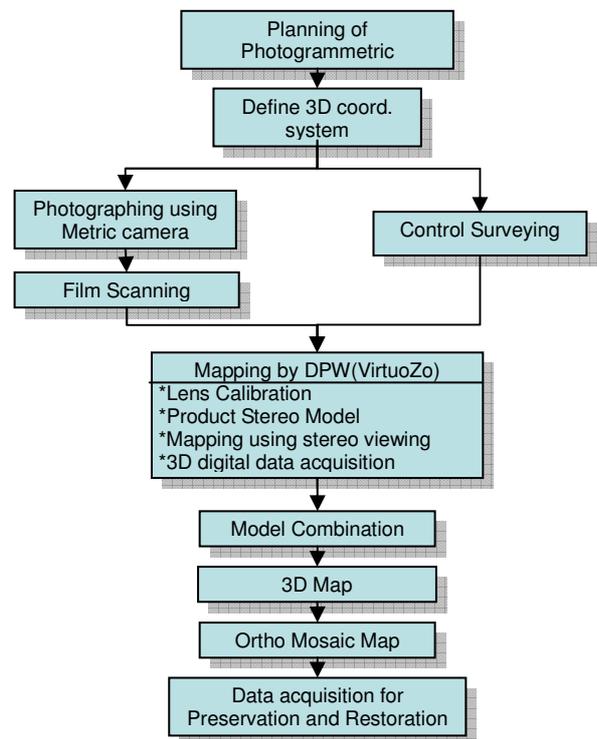


Figure 1 Research Flow Chart

sectors and planned to form total 36 models. Those exposure stations were determined with respect to the size of an object, angle of view of a camera, surrounding conditions of an object and expression of detailed patterns. Conditions on each exposure stations were planned as shown in Figure 2 and dimensional images were acquired. Figure 2 describes 62

exposure stations and reference lines related to all planes of an object. 3D orthogonal coordinates were formed as the direction parallel to that of a reference line was X-axis, photography direction was Z-axis and the direction perpendicular to Z-axis is Y-axis, for analyzing 3D coordinates of an object.

For applying digital photogrammetry, this study used Photo Scanner(Minimum Pixel Size: 7.5 μ) that enabled self-compensation on image distortion caused by scanning. Film

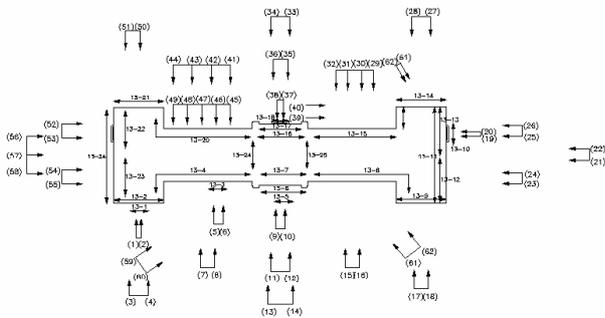


Figure 2 Scheme of exposure plan.

images were converted to digital images of high resolution

While pixel sizes are very important in determining resolution, if pixel is reduced, a relevant file size becomes increased so that small pixel sizes influence on image processing rates. Thus, with respect to file sizes of images, processing rates of images



Figure 3 Aerial Photography of Site

and analysis accuracy, pixel sizes were defined as 15 μ m for facilitating effective image analysis on a computer. In addition,

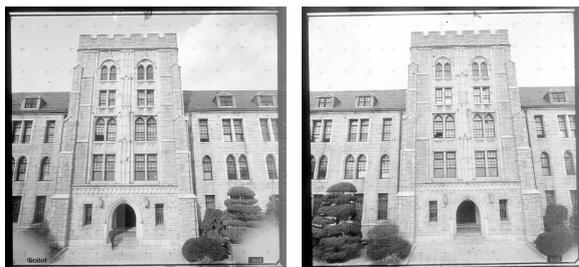


Figure 4 Stereo digital Images

aerial photography on relevant area was used to make a site

map around an object and roof plan. The scale of aerial photography taken at an altitude of about 800m was 1:5,000.

Two dimensional pictures were used for preparing digital site plans. For this purpose, aerial photography was scanned with the resolution of 15 μ m using Photo Scanner and then was converted to digital images to generate drawing. Figure 3 shows aerial photo on the main building of Korea University, an object, and surrounding areas.

3. MEASUREMENT OF REFERENCE POINT

For acquiring 3D digital data for all planes of a structure, it is required to unify coordinate system which is called the same coordinate system. For measuring reference points on the same coordinate system, coordinates of reference points on four planes of a structure were measured using Monmos(Sokkia) 3D Station and connection points linking each plane were also arranged and measured. Moreover, for examining reliability of measured values check points were evenly distributed for verifying accuracy. Target sizes were set to be taken with

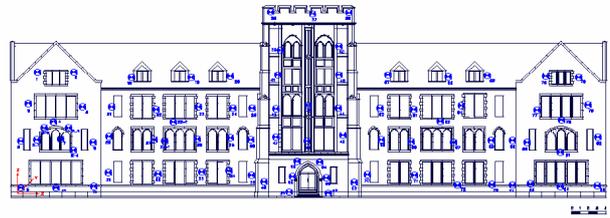


Figure 5 Distribution of Reference Points (Front Side)

minimum 30 μ on captured images. For measuring reference points, reflective targets were installed on the center of target. Reflective targets were 0.4 μ thick and RS10, RS20 and RS30 were prepared according to distances. They were evenly distributed on a relevant plane. Figure 5 describes the distribution of reference points arranged on the front side of an object. At least 6 reference points were distributed on each dimensional model. And the number of reference points was adjusted and arranged in consideration of analysis area of a model and photography conditions around an object. The origin and the reference line defining a coordinates system were set in parallel with an object plane with the front line of 5.1094m, 10m from the front side (front.1) of a building. Then, 3D coordinates system established with X-axis as the reference lie and Z-axis as the photography direction. In this case, multiple connection points and check points were arranged with respect to the size of an object so that all reference points were located on the same coordinates system. Deviations in X-axis, Y-axis and Z-axis caused by movement of Mono Mobile 3-D Station were adjusted to be within 0.5mm each. According to rearrangement of all planes of an object, rearrangement error was 1/13,000 that could be considered as a proper result. It was also confirmed that all reference points were measured in conformity with required precision.

4. ACQUISITION OF DIGITAL 3D MODEL

For acquisition of 3D digital data using digital images, VirtuoZo Software was used as a digital data acquisition system. VirtuoZo entered coordinates of reference points acquired by Mono Mobile 3-D Station after creating new blocks and entering detailed information on a camera. Next, digital data was converted to files in a format that could be recognized by VirtuoZo. After interior and exterior orientation for left and right images, dimensional models were generated and drawn. For special areas requiring precise drawing, Image Resampling

was applied and Image Matching procedure was carried out. For images completing matching procedure, precise drawing on an object was conducted using 3D Digitizing Module connected to MicroStation. For digital images, orientation, image resampling and image matching were performed and then, 3D precise drawing for total 36 models were conducted

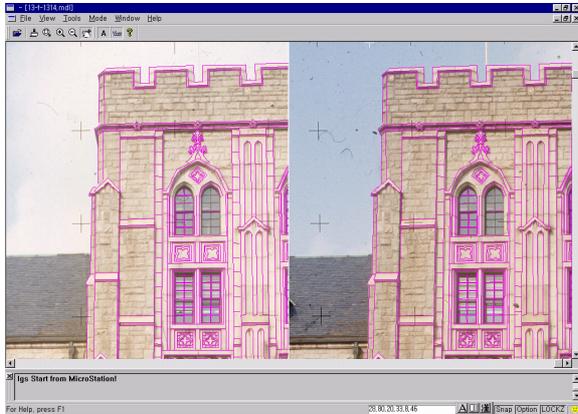


Figure 6 digital Drawing Screen for Dimensional Images

using 3D digitizing module connected to MicroStation, GIS processing software. Orientation procedure in the process to get digital data consists of interior orientation, relative orientation and absolute

were 0.001 to 0.01, and most models showed deviation less than 0.005. average standard error was 0.0025 to 0.036, with slight variations. However, all models achieved orientation with accuracy below predefined limit. Table 1 explains parts of results for interior and relative orientation. Figure 6 describes working screen for digital drawings on main

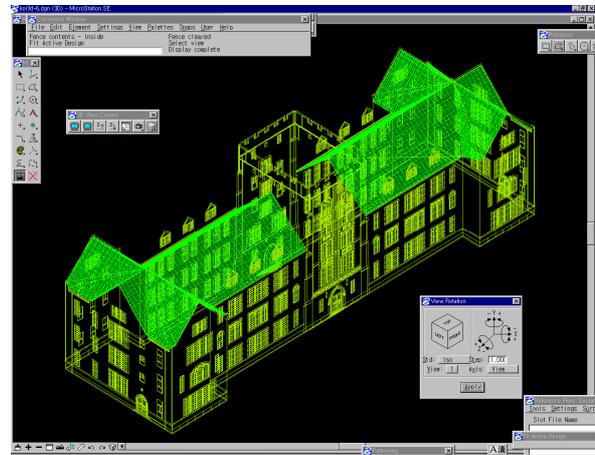


Figure 7 3D digital Drawing Results

tower sectors on the front plane of an object and Figure 7 illustrates the results of digital drawing using ISO View method among display methods. And that formed 3D drawing for the

Table 1 Results of Interior and Relative Orientation

Img #	Interior Orientation				Model #	Relative Orientation		Img #	Interior Orientation				Model #	Relative Orientation							
	Transform Matrix		Accuracy			Rotation Factor	RMSE		Transform Matrix		Accuracy			Rotation Factor	RMSE						
F01	0.997580	-0.005959	Mx	0.009	F1020	κ(1)0.0026 κ(2)0.0095 ω(2)0.0067 φ(1)0.0501 φ(2)0.0731	0.0079	F05	0.997762	-0.008784	Mx	0.009	F0606	κ(1)0.0376 κ(2)0.0286 ω(2)0.0064 φ(1)0.0457 φ(2)0.0507	0.0064						
	0.005633	0.997082	My	0.008					0.008639	0.997082	My	0.007									
F02	0.997635	-0.018478	Mx	0.009				F06	0.997538	-0.015302	Mx	0.006				F07	0.997863	0.000420	Mx	0.007	
	0.018431	0.997270	My	0.005					0.014829	0.997106	My	0.009					-0.000784	0.997499	My	0.006	
F03	0.997964	0.002032	Mx	0.008				F0304	κ(1)0.0599 κ(2)0.0577 ω(2)0.0029 φ(1)0.00224 φ(2)0.0107	0.0127	F07	0.997073				-0.000225	Mx	0.007	F0708	κ(1)0.1459 κ(2)0.1370 ω(2)0.0041 φ(1)0.0535 φ(2)0.0140	0.0018
	-0.002431	0.997481	My	0.004								0.997966				0.007585	Mx	0.009			
F04	0.997073	-0.000225	Mx	0.007	F08	-0.007657	0.997379				My	0.005									
	-0.000087	0.996697	My	0.006																	

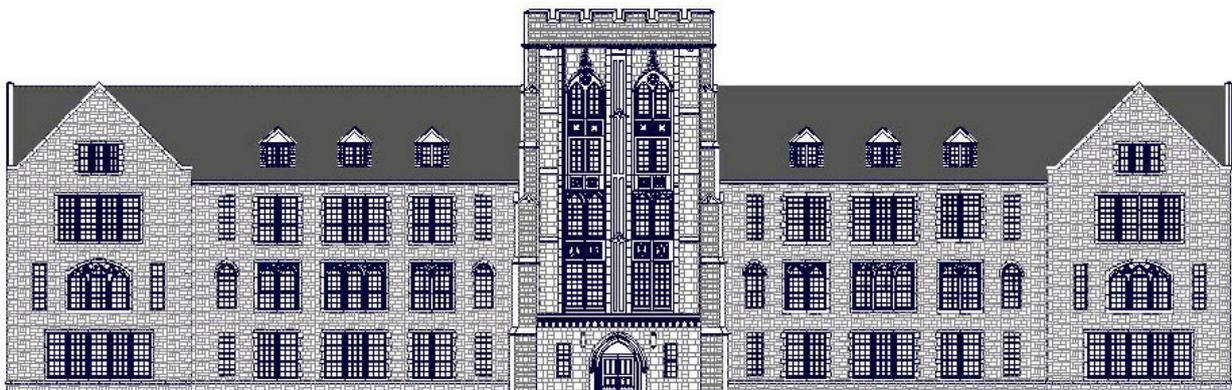


Figure 8 Combined digital map of the Front Plane of an Object

orientation determining 3D space, and this procedure has a substantial influence on accuracy of digital data. This study set the accuracy limit of interior orientation and relative orientation within 0.01 and 0.1 apiece. The accuracy of X and Y coordinates related to interior orientation for total 36 models

front plane of an object as mixing performances of digital drawing using performances of reference points acquired on the same coordinates system, which used ISO View method among display methods. Performances by digital drawing were mixed using

measurement of reference points between adjacent models on MicroStation. Figure 8 shows elevation generated by editing performances of digital drawings in two dimensions related to front plane of an object using Virtuoso system.

5. PRODUCTION OF ORTHO IMAGE

Orthographic images mean images acting as plane figure as showing central projection objects on orthographic position.

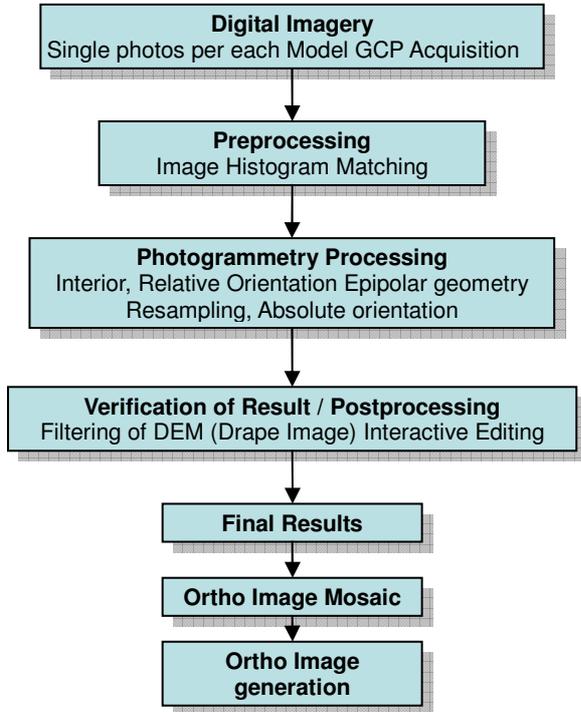


Figure 9 Orthographic Image Generation Flow

express an object map with symbols and lines by images of an object so that they can be used like a map in directly measuring distances, angles, locations and dimensions. Like general aerial photography, close-range photogrammetric survey results are also influenced by central projection principles. Then, like performances of aerial photography in which objects are subject to displacement because of geography and landform, orthographic images also have some displacement according to landform. Thus, acquiring orthographic images and applying them in close photographic surveys will improve efficiency of surveys. Therefore, this study tries to generate orthographic images using orthographic rectification approach related to the main building of Korea University and then perform 3D modeling on the basis of the same coordinates system using acquired DEM and drawing performances on the front plane of an object. Figure 9 describes general process for creating orthographic images.

5.1 Digital Images and Reference Points

6 sheets of digital image data on the front plane of an object were used for creating orthographic images. Reference points were selected as specific points among vector data on digital drawings and coordinates performances on the same coordinate system. The target plane was divided into 5 sectors to creating orthographic images and those sectors were reshaped into one plane using reference points after image analysis. Each image has a different brightness according to photography conditions. So each image was enhanced using linear stretching for histogram matching. Then, different average values and standard deviations of digital images were regularly compensated on the basis of brightness data on Picture 4. Next, images had same color distributions by equalization. Figure 10 displays divided sectors for creating orthographic images for the front plane of an object and Figure 11 presents histogram of digital images used.

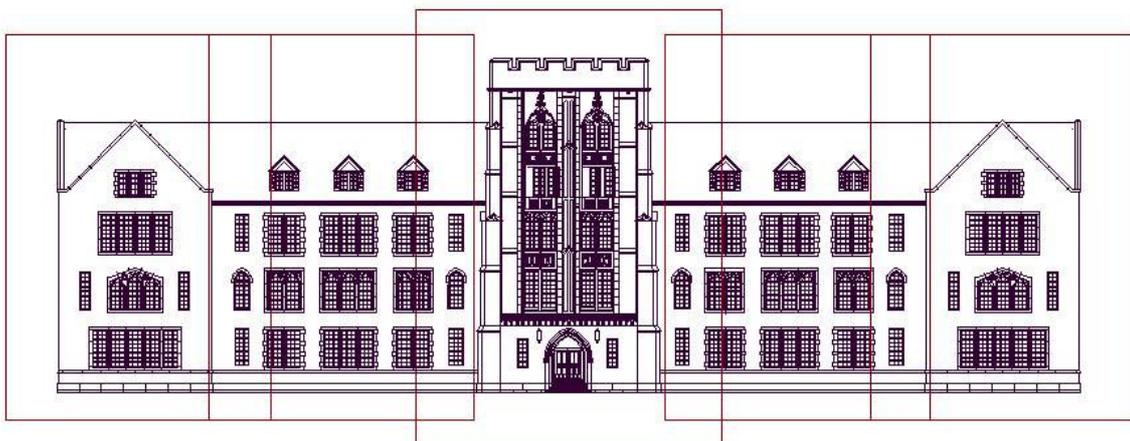
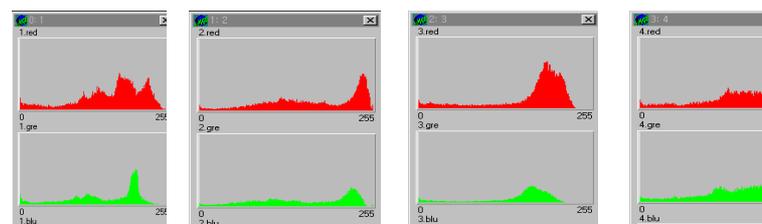


Figure 10 Sectors Divided for Creating Orthographic Images

That is, orthographic images have only one difference that they



5.2 DEM Creation and Editing

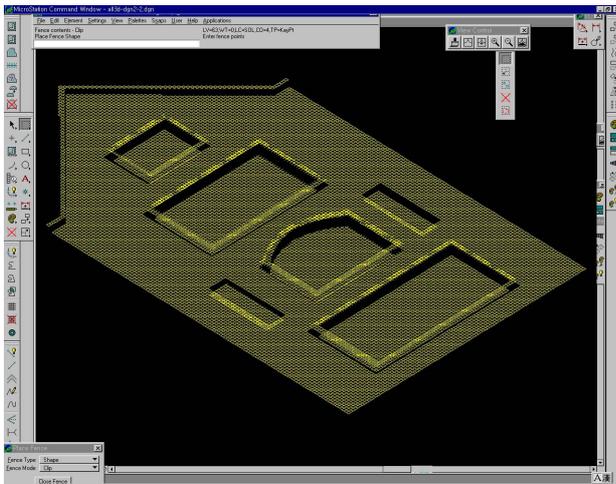


Figure 12 DEM (GRID Model)

Digital Elevation Model (DEM) is 3D data format analyzing and expressing surfaces of an object by 3D modeling, which is the major element for geographic data processing. For creating and editing DEM, MTA (MGE Terrain Modular) was used and so TIN model and Grid model were generated. Grid structure, advanced 2D matrix, can easily manipulate elevation matrices. Then, this study used Grid model to create DEM. Figure 12 illustrates Grid model layout generated and edited on MTA to create orthographic images.

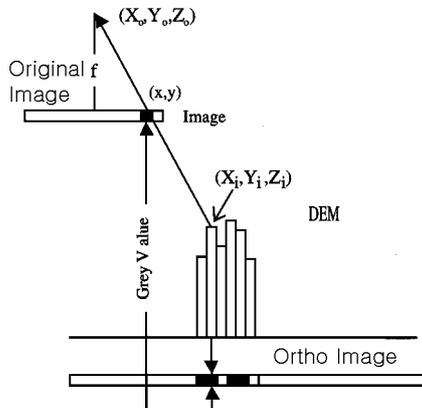


Figure 13 Digital Ortho Rectification

5.3 Creation of Orthographic Images using DEM

ER-mapper 6.1 was used for creating orthographic images and orthographic rectification approach was applied using reference points. Orthographic image creation using digital displacement correction approach conducts correction with

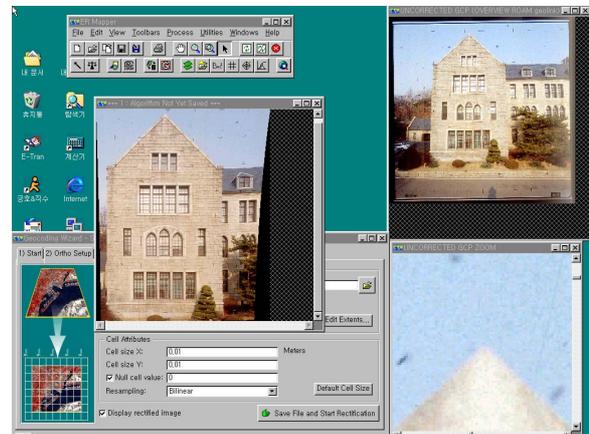


Figure 14 Ortho Image (ER-mapper6.1)

respect to exterior orientation factors, interior orientation factors, focal distances and collinearity conditions during the process to move DN values of original images to image coordinates of DEM. It adopts the principle as shown in Figure 13. After substituting 3D ground coordinates of each pixel of DEM to collinearity condition formula, images were converted to original image coordinates. Brightness was determined by interpolation on pixels around corresponding original image coordinates and saved on each pixel position of DEM.

Figure 14 describes orthographic images acquired for digital images of an object. At this point, bilinear interpolation was applied to interpolation of images and regenerated to 10.6 orthographic projection images were tessellated on Intergraph Image Analyst. Acquired mosaic images were edited using Photoshop5.0 for correction on mosaic seam. Figure 15 shows orthographic image outputs before editing related to each digital data and Figure 16 presents combined images of orthographic images and vectors corrected by Photoshop. Contour and orthographic images of a target showed proper matching through correction of distortion.

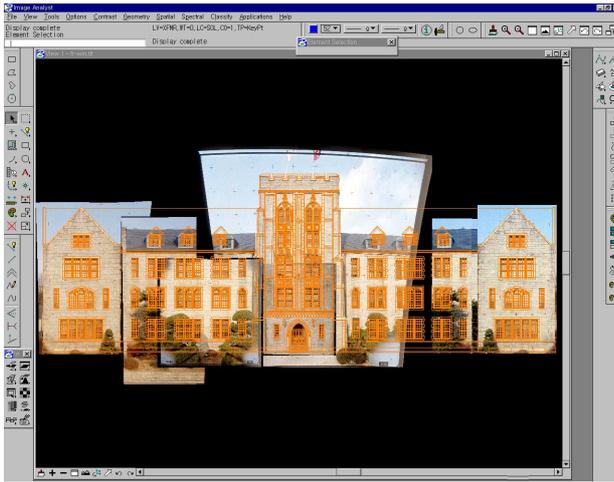


Figure 15 Preliminary Orthographic Images

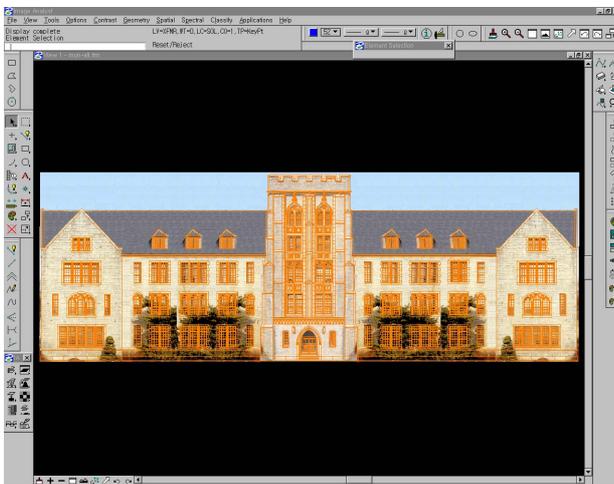


Figure 16 Combined Orthographic Images and Vector Data

6. CONCLUSION

According to measurement on a cultural asset by digital photogrammetry, this study identified the conclusions as described below.

1. Digital photogrammetry facilitates more effective acquisition of 3D digital data for large cultural assets and enables to produce a variety of drawings such as elevation required for space analysis.
2. It is able to understand digital drawings as creating orthographic images using digital images and 3D drawings and linking those performances to vector data and to provide data for more effective visual analysis.
3. Beyond existing measurement approaches for cultural assets, digital photogrammetry enables more accurate and effective quantitative analysis. Acquired 3D digital data can be corrected, updated and permanently preserved so that it is expected that those data will be useful in setting plans for diagnosis or preservation of cultural assets.

REFERENCE

- A.Gruen, E.Baltsavias, 1990, Close-Range Photogrammetry Meets Machine Vision, SPIE.
- A.Gruen, 1997, Automatic Extraction of Man-Made Objects from Aerial and Space Image, The Univ. of Southwale.
- Andrew R. Marshall, 1991, Network Design and Optimization in Close Range Photogrammetry. The Univ. of Southwale.
- Bae, Yeon-Seong, 1990, Precise Measurement for Circular Structure by Non-Measurement Camera, Master's Thesis, Chungnam University.
- Cliff Greve, 1996, Digital Photogrammetry, ASPRS.
- C.S.Fraser, 1982, Optimization of in Close-range Photogrammetry, ASCM-ASP 48th Annual Convention Technical Papers, pp.194-209.
- Ferdinand van der Heijden, 1995, Image Based Measurement System, John Willey & Sons.
- Karara h.m., 1976, Non-Topographic Photogrammetry, 1972-1976, PE&RS, vol.42, No.1. January, pp 37-45.
- Kang, Joon-Mook, 1984, 3D Precise Analysis on a Target by Multiple Close Photogrammetry, Doctoral Dissertation, Yeonsei University.
- Kang, Joon-Mook, 1997, General Thesis on Sinjong of King Seongdeok, General Report, Gyeongju National Museum.
- Kang, Joon-Mook, 1998, 3D Orientation Techniques using Measured Data on Small Topographic and Underground Structure, Gyeongdong Technology Corporation.
- Sarah Dennett & Hans Muessig, 1980, Archaeological Application for Close range Photogrammetry, ACSM-ASP 46th annual convention, technical papers, pp.335-341.