ORTHOIMAGE CREATING SYSTEM FOR DOCUMENTATION OF RELICS USING ORTHOIMAGER 300

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ABSTRACT

Documenting buried cultural properties is an important task in investigation of a ruin. Line drawings of excavated relics are generally requested in Japan. Currently, most of these line drawings are produced manually from results of direct measurement of the object with a rule. This work takes time and the quality of the produced line drawings depending on skill of an operator is unsatisfactory in some cases. Therefore we have developed a system to create digital orthoimages for producing line drawings of excavated relics using ORTHOIMAGER 300, which is an orthogonal projection imaging device based on telecentric optics and can acquire a digital orthoimage directly. Minimum hardware components of the developed system are ORTHOIMAGER 300, a PC-controlled lens-interchangeable digital SLR camera, and a PC. The developed system can be operated easily by an amateur without photogrammetric or image processing know-how, and provide digital orthoimages of sufficient quality for producing line drawings of excavated relics in a short time. We have been producing line drawings of excavated relics from digital orthoimages created by the system.

1. INTRODUCTION

Documenting buried cultural properties is an important task in investigation of a ruin. Line drawings of excavated relics are generally requested in Japan. Currently, most of these line drawings are produced manually from results of direct measurement of the object with a rule. This work takes time and the quality of the produced line drawings depending on skill of an operator is unsatisfactory in some cases.

Accordingly, utilization of photographs of the object was considered for producing line drawings of excavated relics easily with sufficient quality. However, geometry of photographs is based on perspective projection and a digital surface model (DSM) of the object is necessary to produce an orthogonal projection line drawing of the object. It was found not easy and time consuming to create a digital orthoimage from a pair of stereo images.

Therefore, we adopted ORTHOIMAGER 300 that is an orthogonal projection imaging device based on telecentric optics and can obtain a digital orthoimage directly. This paper reports the development of the system to create a digital orthoimage for producing line drawings of excavated relics using ORTHOIMAGER 300.

2. OUTLINE OF THE SYSTEM

2.1 User requirements

User requirements for a system to create a digital orthoimage for producing line drawings of excavated relics were summarized as follows:

(1) Sufficient quality of created orthoimages for producing line drawings of excavated relics The quality of a line drawing produced from a digital orthoimage created by a system should be equal to or better than that of a line drawing produced by the conventional manual method. The quality of a digital orthoimage created by a system should be required to be very high in neither geometry nor radiometry.

(2) Easy operation A user of a system will be an archaeologist or a technician who has neither photogrammetric nor image processing expertise. An amateur should operate a system easily after short-period training.

(3) Small scale and low cost The conventional manual method for producing line drawings of excavated relics does not require expensive equipment. Hardware of a system should be compact and the cost of a system should be as low as possible. As many of hardware and software components as possible should be for all purposes and available on the market.

2.2 System configuration

We developed an amateur system to create a digital orthoimage from a pair of stereo digital camera images for restoration of cultural heritages (Hongo *et al.*, 2000, Matsuoka *et al.* 2002). Since the developed system was designed mainly for recording the current status of a mural painting in a cave and its image acquisition subsystem was expected to be operated in the cave, the system is rather large-scale and cannot fill the above mentioned user requirements.

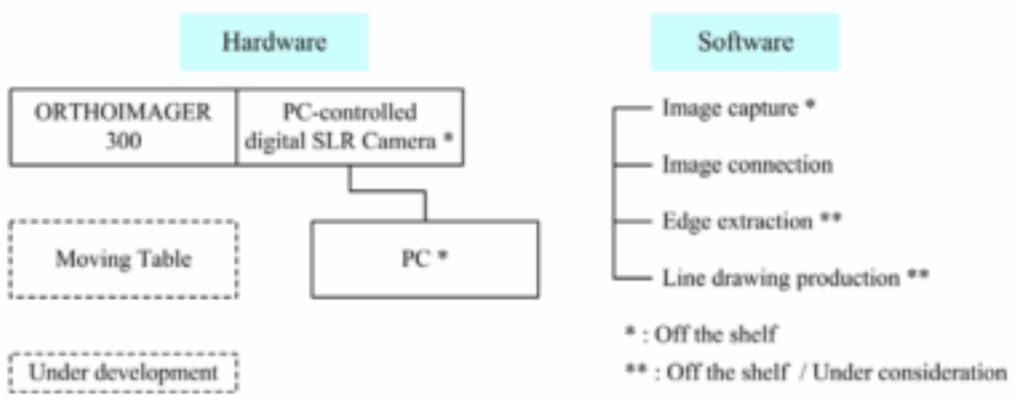

Figure 1. System configuration

Figure 2. ORTHOIMAGER 300

Therefore, we decided to adopt an orthogonal projection imaging device based on telecentric optics that can obtain a digital orthoimage directly. Figure 1 shows the configuration of the designed system grounded on the user requirements.

2.2.1 Hardware configuration: Minimum hardware components of the system are ORTHOIMAGER 300, a PC-controlled lens-interchangeable digital SLR camera, and a PC.

(1) ORTHOIMAGER 300 ORTHOIMAGER 300, the main hardware component of the system, is an orthogonal projection imaging device based on telecentric optics. The basic idea of ORTHO-IMAGER 300 was proposed by Emeritus Professor Shunji Murai. ORTHOIMAGER 300 has been designed by Mr. Akishige Shirasawa and manufactured by Kaiken Co., Ltd. under the leadership of Kokusai Kogyo Co., Ltd.

Figure 3. Orthoimage acquire by ORTHOIMAGER 300

Imaging device	Lens-interchangeable digital SLR camera
Aperture of the telecentric optics	300 mm in diameter
Focal length of the telecentric optics	1200 mm
Effective imaging area (W × H)	262 × 176 mm
Dimensions (W × H × D)	Approx. 330 × 480 × 850 mm
Weight	Approx. 24 kg

Table 1. Specifications of ORTHOIMAGER 300

The chief rays of telecentric optics are parallel to one another. They are also parallel to the optics axis and perpendicular to the image plane that is perpendicular to the axis. The image scale of telecentric optics does not change even if the distance to the object changes. Accordingly, telecentric optics provides an orthogonal projection image. The major fault of an image acquisition device using telecentric optics is that its imaging size of the object is limited to the aperture of the telecentric optics. Since a telecentric lens of large aperture is rather heavy and expensive, ORTHOIMAGER 300 utilizes a parabolic mirror of 300 mm in diameter for ensuring the imaging size of 200 mm × 200 mm in square and reducing the weight and cost of the system. Figure 2 shows ORTHOIMAGER 300 and Figure 3 shows a digital orthoimage of a pottery acquired by ORTHO-IMAGER 300. Table 1 shows the specifications of ORTHOIMAGER 300.

Camera	Nikon D2X	Nikon D2H	Nikon D70
Characteristics	High resolution	Good combination of speed and image quality	High cost performance
Image sensor	CMOS image sensor	JFET imaging sensor LBCAST	CCD image sensor
Image format	Nikon DX Format 23.7 × 15.7 mm	Nikon DX Format 23.3 × 15.5 mm	Nikon DX Format 23.7 × 15.6 mm
Effective pixels	12.4 million	4.1 million	6.1 million
Image size (Full image)	4,288 × 2,848 pixels	2,464 × 1,632 pixels	3,008 × 2,000 pixels

Table 2. Specifications of typical PC-controlled lens-interchangeable digital SLR cameras

ORTHOIMAGER 300 will be also available for recording (2) Image connection software archeological artifacts, biological specimens, medical If an object is larger than the aperture of ORTHOspecimens, mechanical parts, electronic parts, and so on. IMAGER 300, an orthoimage covering the object is
created from several images. We have developed a piece

(2) PC-controlled lens-interchangeable digital SLR camera of image connection software to create a connected The imaging device of ORTHOIMAGER 300 is a lens-orthoimage. interchangeable digital single-lens reflex (SLR) camera controlled by a personal computer (PC) without a lens. (3) Edge extraction software PC-controlled digital SLR cameras manufactured by Nikon Edge images extracted from an orthoimage acquired by Corporation can currently be attached directly to ORTHO-ORTHOIMAGER 300 will assist one to produce a line IMAGER 300. If one utilizes a camera manufactured by drawing. Off-the-shelf photo-retouching software is another manufacturer, a lens mount adapter corresponding currently utilized for edge extraction. We are considering to the camera is necessary to insert between ORTHO-a development of a piece of edge extraction software. IMAGER 300 and the camera. Table 2 shows the specifications of typical Nikon PC-(4) Line drawing production software controlled lens-interchangeable digital SLR cameras. Unit Line drawings of excavated relics, which are the final pixel size of an acquired orthoimage is approximately 80 output of the system, are manually produced from the µm (D2X) to 140 µm (D2H) on the object.

(3) PC automatically from orthoimages. An off-the-shelf personal computer (PC) that has an interface with the digital SLR camera such as IEEE 1394 or USB is required.

(4) Moving table
The major fault of an image acquisition device using telecentric optics such as ORTHOIMAGER 300 is that its imaging size of an object is limited to the aperture of the optics. An orthoimage covering an object that is larger than the aperture of the telecentric optics cannot be obtained by a single shot of the image acquisition device. Consequently, we have to acquire several images covering a large object and connect acquired images to become a mosaicked image covering the whole of the object. A connected image of a large object with sufficient precision is created by software at the moment. A table for moving an object with precise motion control is expected to create a connected image easily with higher geometric precision. We have been developing a table for moving an object.

2.2.2 Software configuration: The only necessary software of the system is a piece of image capture software if all the objects are smaller than the aperture of ORTHOIMAGER 300. Edge extraction software and line drawing production software is beyond the user requirements of the system mentioned in the previous section 2.1.

(1) Image capture software
The digital SLR camera attached to ORTHOIMAGER 300 is controlled by a PC. An orthoimage of an object is acquired under the control of image capture software. The system utilizes off-the-shelf image capture software provided by the camera manufacturer.

(2) Image connection software
If an object is larger than the aperture of ORTHO-IMAGER 300, an orthoimage covering the object is created from several images. We have developed a piece of image connection software to create a connected orthoimage.

(3) Edge extraction software
Edge images extracted from an orthoimage acquired by ORTHOIMAGER 300 will assist one to produce a line drawing. Off-the-shelf photo-retouching software is currently utilized for edge extraction. We are considering a development of a piece of edge extraction software.

(4) Line drawing production software
Line drawings of excavated relics, which are the final output of the system, are manually produced from the orthoimage at present. We are considering a development of a piece of software to produce line drawings automatically from orthoimages.

2.3 Processing flow

Figure 4 shows the processing flow of producing line drawings of excavated relics by using the developed system.

(1) Image acquisition
An orthoimage of an excavated relic is acquired by the digital camera attached to ORTHOIMAGER 300 under the control of image capture software. Since the acquired image is directly transmitted to the PC, one can immediately investigate whether its quality is satisfactory or not. Furthermore, it is necessary to confirm that there is no gap between adjacent images, if an array of images is acquired for the object larger than the aperture of ORTHOIMAGER 300.

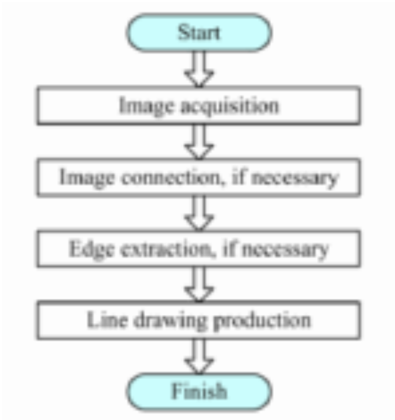

Figure 4. Processing flow

Figure 5. Image capture

Figure 6. Image capture software: Nikon Capture 4

Figure 7. A series of acquired orthoimages

Figure 8. Image connection software

Figure 9. Connected orthoimage

Figure 5 shows a scene of image acquisition, and Figure 6 shows a screen of the image capture software Nikon Capture 4.

(2) Image connection

Figure 7 shows a series of acquired orthoimages of the excavated relic that is larger than the aperture of ORTHOIMAGER 300. These images should be connected each other to become a mosaicked image covering the whole of the object. Figure 8 shows a screen of our developed image connection software. One picks up an image to be connected, and places it in the appropriate cell of an array. After all images to be connected are arranged in the array, relation between adjacent images is examined to determine image geometry of all images by means of clicking at pass points of adjacent images on the screen. Then the PC determines image geometry of all images simultaneously and executes geometric correction of each image following the determined image geometry. Finally geometrically corrected images are automatically connected each other to become a mosaicked image covering the whole of the object. Figure 9 shows a connected orthoimage created from the series of orthoimages shown in Figure 7.

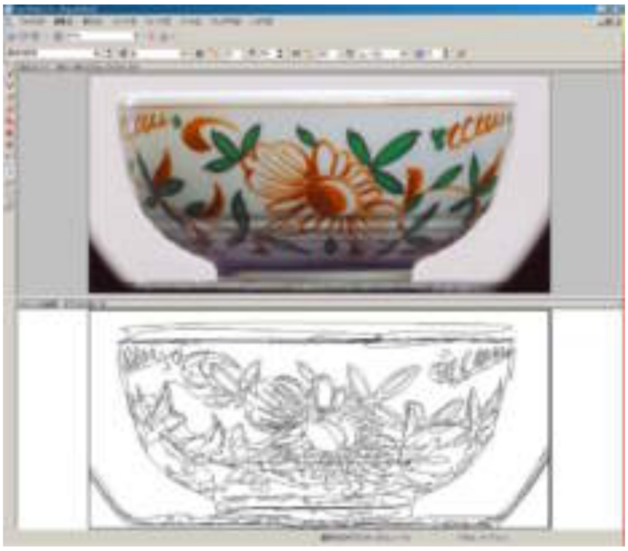

Figure 10. Edge extraction software: CorelTRACE 12

(3) Edge extraction
An edge image extracted from an orthoimage will assist one to produce a line drawing of the object. Figure 10 shows a screen of the off-the-shelf software CorelTRACE 12 to extract edges from an orthoimage.

(4) Line drawing production
A line drawing of the object, which is the final output of the work, is manually produced from the orthoimage at present by using drawing software such as Adobe Illustrator. A piece of software to produce line drawings automatically from an orthoimage is desirable.

Figure 11 shows results produced from an orthoimage of a pottery created by the developed system.

2.4 Comparison with another system

There are few systems to create an orthoimage for producing line drawings of excavated relics in Japan. OrthoScan-1000 shown in Figure 12 is a system using an imaging device based OrthoScan-1000 was designed to acquire an orthoimage of an excavated relic. Table 3 shows the specifications of OrthoScan-1000. OrthoScan-1000 adopted a linear image sensor with a telecentric lens of effective aperture of 150 mm, and is able to acquire an orthoimage of the object up to 1000 mm high × 500 mm wide by two-dimensional scanning of the linear sensor as shown in Figure 13. Since OrthoScan-1000 has a highly precise scanning mechanism, a dedicated illumination, shading correction software and a multi-depth image acquisition technique for compensation of defocusing, the geometric and radiometric quality of an image acquired by OrthoScan-1000 is very high. An orthoimage acquired by OrthoScan-1000 may be competent for digital archives.

(a) Orthoimage acquire by ORTHOIMAGER 300

(b) Patterns extracted from the acquired orthoimage

(c) Cross section drawn manually

(d) Composition of patterns and cross section

Figure 11. Results produced from an orthoimage created by the developed system

Although the quality of an image acquired by ORTHO-IMAGER 300 is worse than that of an image acquired by OrthoScan-1000, the quality of an image acquired by ORTHOIMAGER 300 is competent for producing line drawings of excavated relics. Furthermore ORTHOIMAGER 300 is smaller, lighter and less expensive than OrthoScan-1000. We believe that our developed system using ORTHOIMAGER 300 is a more suitable system as an alternative system to the current manual method of producing line drawings of excavated relics than OrthoScan-1000.

Imaging device	Linear image sensor (7µm / pixel × 5,150 pixels) Two-dimensional scanning
Effective aperture of the telecentric optics	150 mm in width
Effective imaging area (W × H)	1,000 mm × 500 mm (100 µm / pixel) 1,000 mm × 300 mm (50 µm / pixel)
Unit pixel size	50 µm / pixel, 100 µm / pixel
Effective image size (W × H)	10,000 × 5,000 pixels (100 µm / pixel) 20,000 × 6,000 pixels (50 µm / pixel)
Geometric accuracy of the scanning system	20 µm
Dimensions (W × H × D)	Approx. 1,670 × 1250 × 1650 mm
Weight	Approx. 100 kg

Table 3. Specifications of OrthoScan-1000

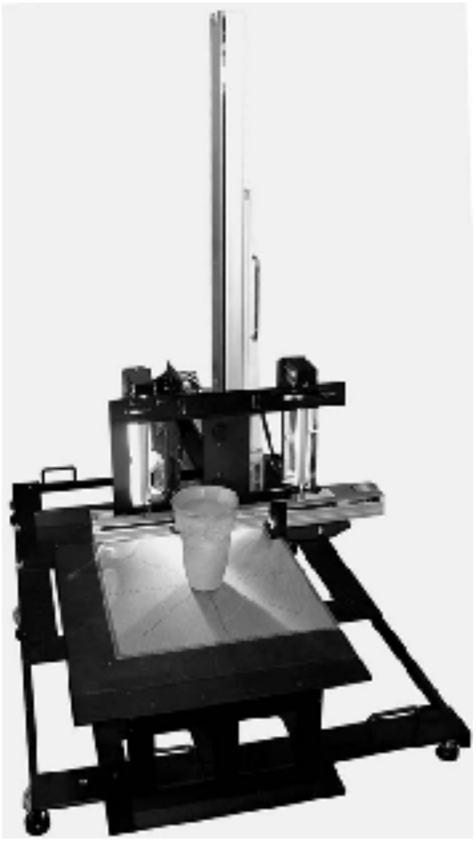

Figure 12. OrthoScan-1000

3. CONCLUSION

We have developed a system to create an orthoimage for producing line drawings of excavated relics using ORTHO-IMAGER 300, which is an orthogonal projection imaging device based on telecentric optics. The developed system can be operated easily by an amateur without photogrammetric or image processing expertise, and provide an orthoimage of sufficient quality in a short time.

We have been producing line drawings of excavated relics from digital orthoimages created by the developed system. We are planning to continue developing the system to add some functions so that the system is more convenient to use.

Orthoimages besides line drawings are expected to be requested in investigation of a ruin in Japan. If an orthoimage itself becomes required, the developed system might be the most useful system for documenting buried cultural properties.

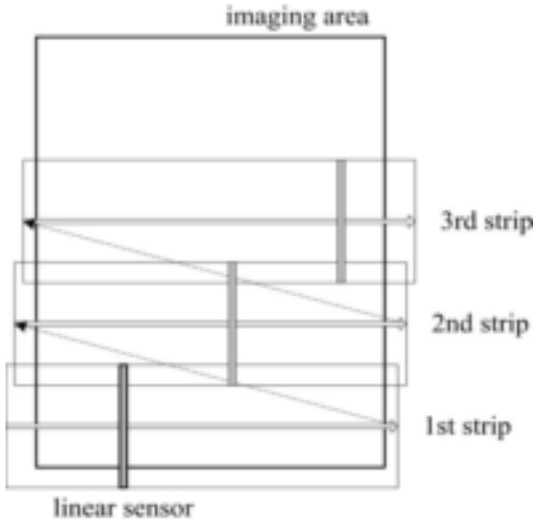

Figure 13. Two-dimensional scanning of linear sensor

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