DEVELOPMENT OF IMAGE-BASED INFORMATION SYSTEM FOR RESTORATION OF CULTURAL HERITAGE

Kenji Hongo*, Ryuji Matsuoka*, Seiju Fujiwara*, Katsuhiko Masuda and Shigeo Aoki****
* Kokusai Kogyo Co., Ltd. Tokyo, JAPAN
kenji_hongo@kkc.co.jp, ryuji_matsuoka@kkc.co.jp, seiju_fujiwara@kkc.co.jp
** Tokyo National Research Institute of Cultural Properties, Tokyo, JAPAN
katuhiko@tobunken.go.jp, saoki@tobunken.go.jp

KEY WORDS: Data acquisition, Database, Image processing, Orthophoto, Photogrammetry, System

ABSTRACT

An image-based information management system for restoration of cultural heritages has been developed. Precise records of the current status of a cultural heritage are necessary to preserve or restore it. Preservation or restoration plan can be made based on the current status of the object. The precise records of the object have been available by photogrammetric technique, but there are too few expensive photogrammetric instruments and experienced photogrammetrists at a heritage site. Accordingly, we decided to develop an amateur system for recording current status of the object by digital cameras, assisting a restoration researcher to make appropriate restoration plans, and then managing information about restoration histories of the object. Our system is based on digital photogrammetry, image processing and GIS technologies, and fundamental data of the system are digital ortho-images made from images acquired by digital still cameras. The system was designed for a restoration researcher who is neither photogrammetrist nor image processing specialist. The major advantage of the system is that it is easy for a nonprofessional to operate it. A restoration scientist without photogrammetric or image processing know-how can operate the system after short-period training. The second advantage of the system is that the hardware of the system is compact and not expensive. Main hardware components of the system are digital still cameras, lighting equipment, a note-type PC, a printer, and a removable storage device. Since all hardware components of the system are for all purposes and available on the market, the cost of the system becomes low.

1 INTRODUCTION

A lot of precious old cultural heritages remain all over the world. These heritages are of great value for human being in both history and art. Some of these old cultural heritages, such as mural paintings of Takamatsuduka tumulus in Nara in Japan, face a crisis that these are going to be collapsed naturally and/or artificially. These become gradually worse by weathering, plants, animals and human activities. Appropriate treatments for these are urgently requested at present.

Although various technologies have been attempted to preserve or restore old cultural heritages, it is the most important to record the current status of the object precisely and preservation or restoration histories of them accurately. These records are necessary to monitor status of both damaged parts and restored parts of the target. A restoration researcher can make an appropriate preservation or restoration plan based on these records.

However, precise and accurate records of an old cultural heritage are not necessarily available. Precise records of the current status of the object have been available by photogrammetric technique, but this photogrammetric work is manual labor and requires a great deal of time and cost. Conventional photogrammetric instruments are too expensive and there is no experienced photogrammetrist working at many heritage sites. And furthermore, since information such as position and extent of damages has been managed usually on an analog map and/or analog inventory, this has made a restoration research inconvenient to make an appropriate preservation or restoration plan.

Therefore we determined to develop an amateur system for recording current status of an old cultural heritage by digital cameras, assisting a restoration researcher to make appropriate preservation or restoration plans, and then managing restoration information such as date, position, treatment method, used chemicals and so on. The system was requested to be such as a restoration scientist without photogrammetric or image processing know-how can operate the system with short-period training.

2 SYSTEM DESIGN

2.1 User requirements

User requests to an information management system for restoration of cultural heritages were summarized as follows:

(1) A system should be operated easily by an amateur.
There are neither enough photogrammetrist nor image processing specialist for restoration of cultural heritages. On the other hand, researchers or technicians engaged in restoration of cultural heritages are not used to photogrammetry nor image processing. A system should be operated easily by a restoration researcher or technician who is neither photogrammetrist nor image processing specialist.

(2) Hardware of a system should be compact and its cost should be low.
A conventional method by analog/analytical photogrammetry needs expensive and somewhat large-scale instruments such as metric cameras and/or analytical plotters. On the other hand a lot of heritage restoration projects in the world are restricted in project budgets for recording of current statuses and restoration histories. Consequently hardware of a system should be compact and the cost of a system should be low. Of course a system should provide precise information enough to preserve or restore old cultural heritages.

(3) A system should be able to manage a great deal and diverse information.
In order to preserve or restore old cultural heritages properly it is necessary to manage a great deal and diverse information about the object. A great deal of information to be managed has been or will be gathered in the form of documents, drawings and images. Some of them are in analog form and the other are in digital form. A system should be able to manage such a great deal and diverse information.

2.2 Features of the system

We have designed a system grounded on above mentioned user requests. Our system is based on digital photogrammetry, image processing and GIS technologies. Digital still cameras acquire fundamental data of the system. A personal computer (PC) creates digital ortho-images from images acquired by digital still cameras. Information management subsystem running on a PC manages information about current status such as healthiness and/or damages, and preservation or restoration records. And furthermore, the system assists a restoration researcher or technician to make a preservation or restoration plan.

Major features of our system are as follows:

(1) Easy operation
The major advantage of our system is that it is easy for a nonprofessional to operate it. Short-period training makes a restoration researcher or technician without photogrammetric or image processing know-how to operate the system. And there is no need for ground survey of control points. Main manual operations of the system are image acquisition by digital still cameras and simple operations of a PC.

(2) Small scale and low cost hardware
Recent advancement of digital image processing technology makes it possible to obtain almost equal results by small scale and low cost hardware designed for nonprofessional purposes to some obtained by conventional analog/analytical photogrammetric instruments. We adopted a PC-controllable digital still camera that is not designed for photogrammetry in place of a metric camera, and a PC for multi-purpose in place of an analytical plotter.

(3) Integrated information management system based on digital ortho-images
All information is managed by database management system (DBMS) based on digital ortho-images. An operator of the system inputs information about damages of the object and preservation or restoration histories viewing a digital orth-image shown on a PC display. This input information is stored into a database (DB) with reference to the position on the ortho-image.

(4) Two-stage image acquisition
Spatial resolution of low-price digital still cameras for nonprofessional use was worse than one of analog cameras last year when we designed the system. Accordingly, we adopted two-stage image acquisition method to ensure information precise enough to preserve or restore old cultural heritages. See below 2.3 for further details.

2.3 Processing flow

Processing flow of the system is similar to one of a conventional method by analog/analytical photogrammetry. Figure 1 shows the flow of the standard processing of the system.

(1) Image acquisition by digital still cameras
It takes a long time and a high cost to take stereo images all over the object with spatial resolution requested for restoration purpose. Therefore we adopted a two-stage image acquisition method for saving time and cost. At the first stage, a pair of stereo images covering the whole object is acquired. We call this pair of images index images. Index images are used for extraction of DEM used at generation of digital ortho images, and for orientation of detailed images that are acquired at the second stage. Spatial resolution of index images is worse than requested resolution of a digital ortho-image used in the restoration information management subsystem, but is sufficient for both DEM extraction and orientation of detailed images. At the second stage, detailed images are taken with spatial resolution requested for restoration purpose. It is not necessary to take a stereo pair image or to cover all over the object. A detailed image is taken of an interesting part of the object, and it is referenced to an ortho mosaic image of index images. Both index and detailed images are acquired by a digital still camera that is controlled by a note-type PC.

(2) Orientation of images
Positions of control points and pass points on images are measured on a PC display. Orientation of index images is executed by the bundle adjustment. A scale such as a staff in leveling taken in an image gives a scale of the model. A mosaic orth-image of index images is utilized as a base map at orientation of each detailed image.

(3) Generation of mosaic ortho-images
DEM for generating ortho-images of index and detailed images are made from index images. Extraction of DEM is executed automatically in principal. All of acquired index and detailed images are transformed orthographically. Finally each ortho-image is connected with the other, and mosaic ortho images of index images and detailed images are generated. After this we call mosaic ortho images of index images and detailed images mosaic index image and mosaic detailed image respectively.

(4) Mapping of damaged area and restored area on a mosaic detailed image
A restoration research maps current status of the object on a mosaic detailed image. The extent of a damage such as mold, exfoliation, scratch, peel off, hole and salt damage are mapped, and supplementary information is stored in a DB with reference to the position. A restoration research also indicates the extent of a restored area, and inputs supplementary information into in the DB with reference to the position.

(5) Retrieval of information about damage or restoration
A restoration research can retrieve any information about damage status and/or restoration histories of the object, and obtain retrieval results in the form of tables, figures and images.

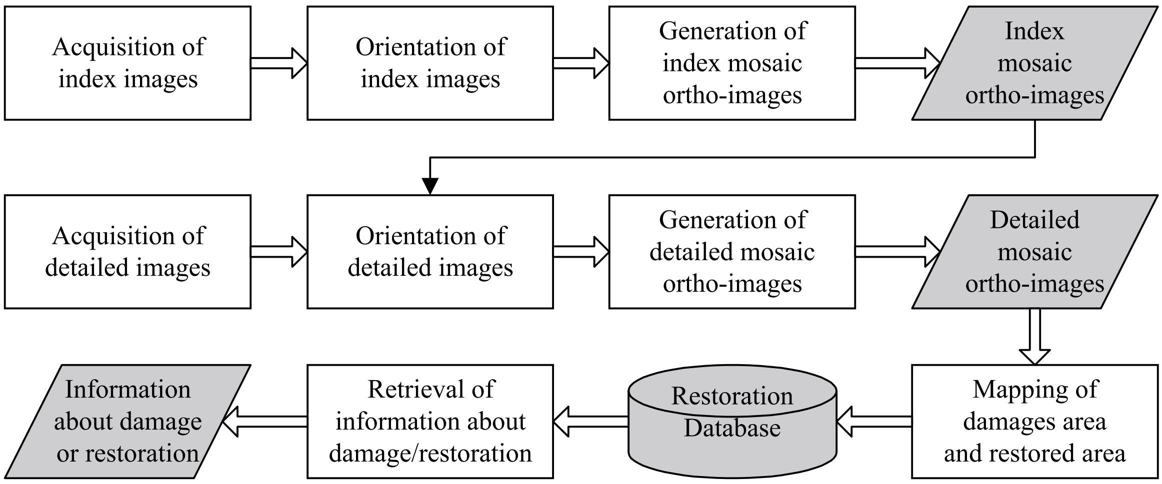

Figure 1. Flow of the standard processing

2.4 System configuration

2.4.1 Hardware configuration of the system

Minimum hardware compositions of the system are a note-type PC, a PC-controllable digital still camera with more than mega pixels, lighting equipment and a scale such as a staff in leveling. Standard hardware compositions of the system are a desktop PC, another digital still camera, another scale, a color printer, and removal storage device such as magneto optical disk drive in addition to the above minimum compositions. This hardware configuration is satisfied with the user request of small-scale and low-cost hardware. Figure 2 shows standard hardware configuration. The left part of Figure 2 shows hardware for image acquisition at a heritage site and the right part shows hardware for image processing and analysis in an office.

All hardware components of the system are for all purposes and available on the market. The most expensive component of the system is a PC-controllable digital still camera. In the autumn of 1998 we got a digital still camera with 1,280 pixels by 1,000 lines and a 28 mm lens at approximately 8,000 US$, but we can now obtain a digital still camera with 3,040 pixels by 2,016 lines and the same lens at the same cost.

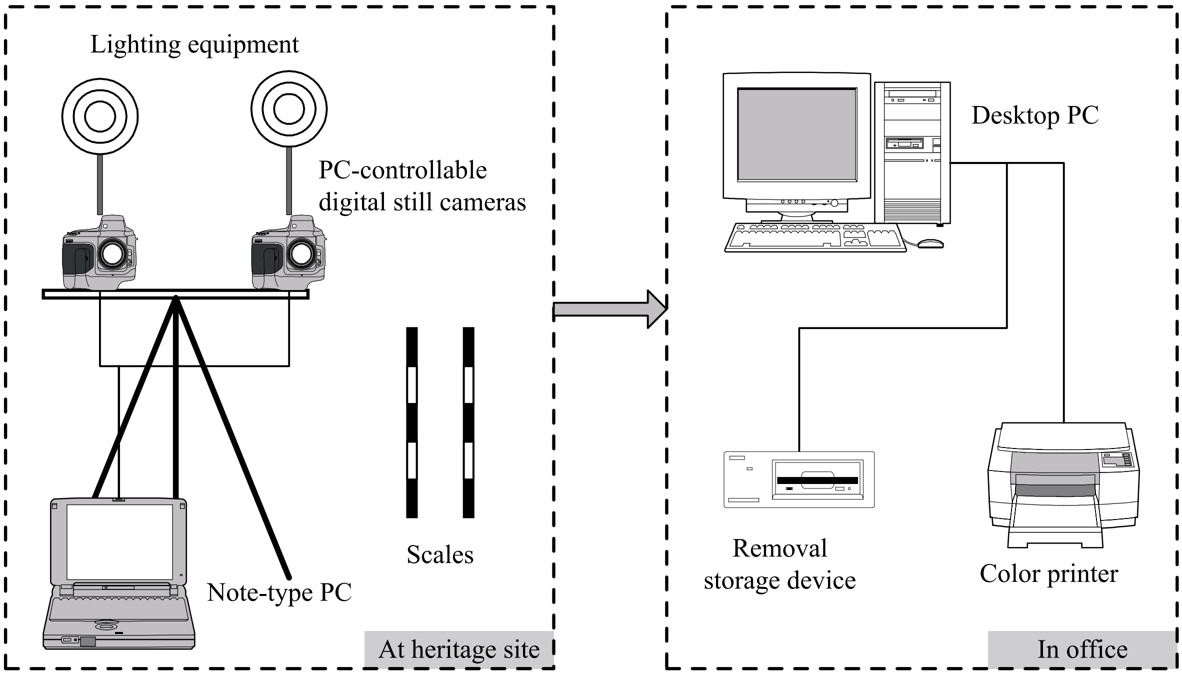

Figure 2. Standard hardware configuration

2.4.2 Software configuration of the system

As shown in Figure 3 the system consists of the following three subsystems:

(1) Image acquisition subsystem
(2) Ortho-image generation subsystem
(3) Restoration information management subsystem.

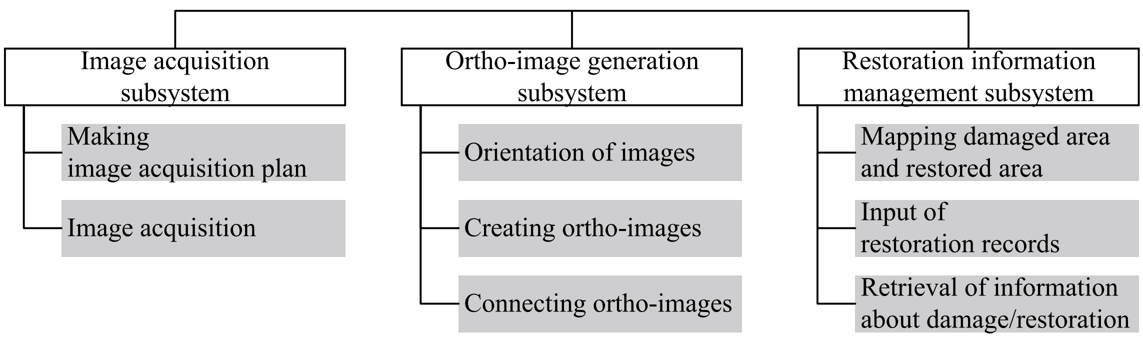

Figure 3. Software configuration

2.4.3 Image acquisition subsystem

Hardware of the image acquisition subsystem consists of a note-type PC, digital still cameras with more than mega pixels, lighting equipment and scales such as a staff in leveling as shown in Figure 2.

The system can make an image acquisition plan according to the size of the object and the limitation of space in front of the object. Whether a research accepts the proposed image acquisition plan or not, images are acquired by a digital still camera controlled by a note-type PC. An aperture of lens and a shutter speed of a digital still camera can be controlled by a PC, and a PC can release the shutter of the camera. Image data are transmitted to the PC as soon as taking the image, and the PC registers the transmitted image with information about the image taking condition in the DB of the system. Control of a digital still camera by a PC enables an amateur photographer to obtain proper images easily because quality of a taken image can be confirmed in real time. A scale taken in an image gives a scale standard.

Figure 4 shows a scene of image acquisition by a digital still camera controlled by a note-type PC.

Figure 4. Image acquisition

2.4.4 Ortho-image generation subsystem

The ortho-image generation subsystem needs only a PC at the minimum. This subsystem usually runs on a PC not at a heritage site but in an office.

Software of this subsystem is based on digital photogrammetry and image processing technologies. Images acquired by the image acquisition subsystem are transferred into this subsystem. Then this subsystem creates an ortho-image of each image and a mosaic image by connecting the ortho-images. This subsystem shows a pair of index images at processing of index images, or a mosaic index image and a detailed image at processing of detailed image on a PC display, and a user indicates some control points and/or pass points in both images on the display. This is the major task for a user to do in this subsystem. Orientation of images is performed by the bundle adjustment with geometric constraints. A mosaic index image and a mosaic detailed image are created automatically and registered in the DB of the system.

Figure 5 shows a screen for measuring image coordinates of control points. Measurement of image coordinates of control points is the major manual operation of this subsystem.

2.4.5 Restoration information management subsystem

The restoration information management subsystem needs only a PC at the minimum. A color printer is very useful in this subsystem. This subsystem usually runs on a PC not at a heritage site but in an office.

Software of this subsystem is based on GIS technology. This subsystem can manage information about the current damage status and restoration records of the object. The mosaic detailed image created by the ortho-image generation subsystem is used as a background image in this subsystem. A user inputs some information about current status of the object or restoration records of the object on the mosaic detailed image displayed on the PC screen. Information stored in the DB of the system can be retrieved complying with a user request. For instance a restoration researcher can obtain statistics of damaged areas in the form of a table, and position and extent of areas restored in the last 2 years in the form of a map.

Figure 6 shows a screen for mapping damaged area on the mosaic detailed image. Mapping of restored area is conducted on a similar screen.

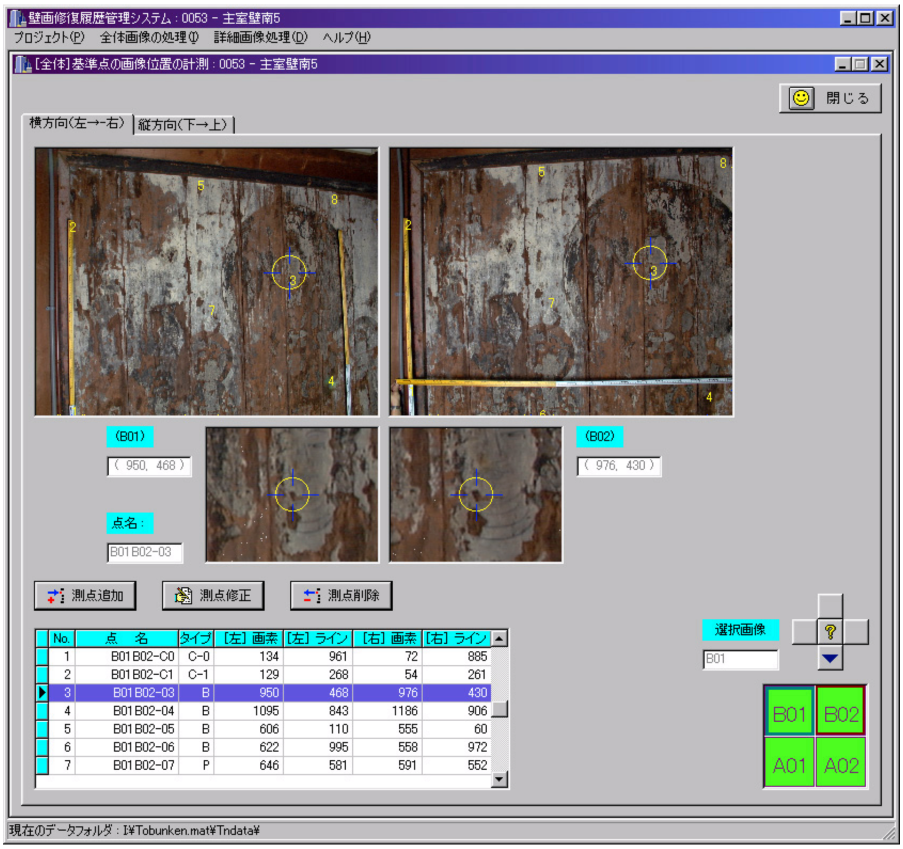

Figure 5. Measurement of image coordinates of control points

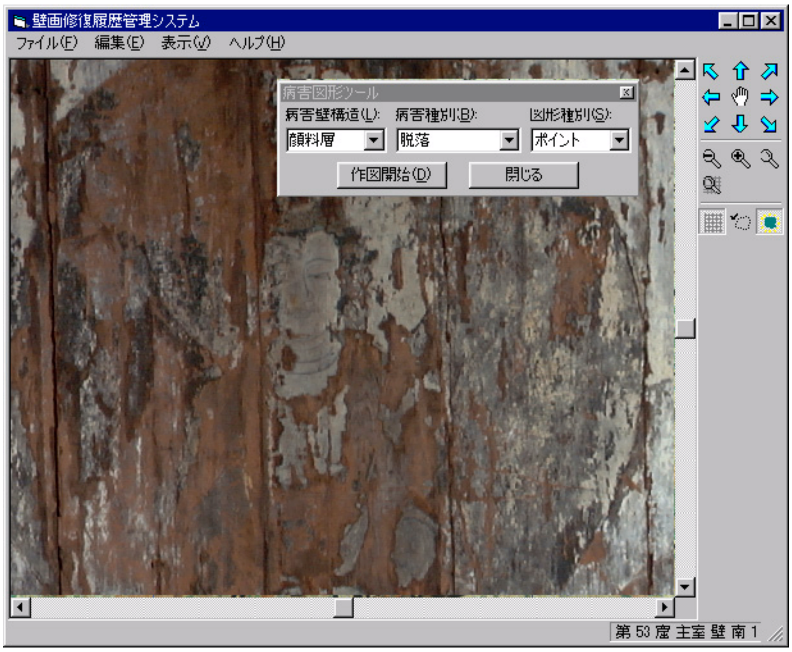

Figure 6. Mapping of damaged areas on the mosaic detailed image

3 EXPERIMENT

We conducted an experiment to investigate performance and user-friendliness of the developed system in May 1999. The experiment was mainly for image acquisition subsystem and ortho-image generation subsystem. The object of the experiment was a mural painting of Shomyoji, one of the famous temples in Yokohama, Japan. The mural painting on the wooden board is 3.6 m wide and 2.4 m high.

4 pairs of index images (2 columns by 2 rows) were necessary to be acquired due to limited space in front of the wall. At that time the object distance was approximately 2 m. 30 detailed images (6 columns by 5 rows) were acquired with the object distance of approx. 0.8 m. The spatial resolution of the mosaic ortho-images of index images and detailed images are 1.25 mm and 0.625 mm respectively. Figure 7 shows an example of a pair of index images and Figure 8 shows examples of detailed images.

Figure 7. Example of a pair of index images of a mural painting of Shomyoji

Figure 8. Examples of detailed images of a mural painting of Shomyoji

Figure 9 shows the whole of a mosaic index image of the mural painting. This image was utilized for processing of detailed images. Figure 10 shows the whole and a part of a mosaic detailed image respectively. Some area with not uniform brightness can be found in Figure 10 (a). This was caused by halation at the surface of the mural painting, and indicates that photography of the old paintings on wooden board is a little difficult.

There were some inconvenient parts found in the system through the experiment. Most of them were as far as user-friendliness and no serious problem in performance was found. All problems found through the experiment have been fixed.

Figure 9. Mosaic of index ortho-images of a mural painting of Shomyoji

(a) Whole (b) Part

Figure 10. Mosaic of detailed ortho-images of a mural painting of Shomyoji

4 CONCLUSION

We have developed an image-based information management system for restoration of cultural heritages. The system is an amateur system for recording current status of the object by digital still cameras, assisting a restoration researcher to make appropriate restoration plans, and then managing restoration history. It is possible for a restoration scientist without photogrammetric or image processing know-how to operate the system with short-period training. Hardware of the system is compact and not expensive because all hardware components of the system are for all purposes and available on the market.

We hope that the system will be of much help to restoration researchers in grasping the current status of cultural heritages, making a restoration plan, and furthermore managing restoration records.

ACKNOWLEDGEMENTS

The authors are grateful to Mr. Chisho Sugata, the head priest of Shomyoji for his help at the experiment of the system.