A CASE STUDY FOR THE PRACTICAL USE OF 3D DIGITAL ARCHIVE OF CULTURAL PROPERTIES

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ABSTRACT:

A scanning device generally referred to as a "laser scanner", used to obtain 3D data of objects by irradiating laser beams, is used in the field of cultural properties, and is starting to achieve significant results. The technique to record complex 3D data with high accuracy and speed, without touching or destructing an object, makes it an essential tool in the field of cultural properties, as well as arousing interest in the displaying of such data on a computer, and in the various possible usage of the obtained 3D images.
The authors have implemented this laser scanning technique to obtain data for such various fields as architecture, fine arts, monuments, and historic sites, with good results. This paper is written to consider application of this technique for efficient conservation of cultural properties, referring to the 3D laser scanning activities performed by authors up to the present.
The 3D digital archive making with laser scanner requires two steps, which are actual measurement works and digital processing of the data acquired. The acquired point clouds in three dimensions can be displayed on a computer by using the exclusive software and we have to process (align, merge and so on) these data considering subsequent works also.
Up to the present, the authors have performed many practical applications using 3D digital archives of cultural properties measured by laser scanner. These are valuable records for various purposes: handing over to future generations, creating 2D information, investigating inclinations, preparing basic data for examination of a restoration plan, visualizing CG animations and others.
In this paper, the authors wish to introduce the method of measurement using laser scanner, and the subsequent processing of the obtained data, in order to clarify the validity and possibility of application for creating efficient and valuable digital archives.

1. INTRODUCTION

Cultural heritage is a memory of human history and footprints in the sands of time, giving a glimpse of humankind's way of life, technology, and wisdom that emerged and dominated various periods of time in which they were made. They are vulnerable to natural wear and tear, not to mention damage caused by disasters. In fact, we have been constantly losing cultural heritage, whether we know it or not.
At the same time, we have been striving to preserve them in their original state or condition, as much as possible, in order to bestow them onto the next generation. Our 3D laser scanning technology is one way to archive this objective.
Although laser-scanning technology can be applied for a wide variety of areas, in this paper, the method of actual laser scanning, processing point cloud data, and the practical use of data will be explained, with some practical examples.

2. PROCESS OF 3D DIGITAL ARCHIVES

2.1 The Laser Scanner

Various types of laser scanners have been developed, and the principle of measurement, accuracy, speed, density, range, and price are different for every type of laser scanner. In laser scanning, it is important to choose the optimal scanner depending on the object to be measured and the purpose of measurement. In recent years, research on performance comparison of these laser scanners, including the accuracy of point cloud data obtained, have been performed.
As for typical principle of the measurement, there are two kinds, "time of flight" and "triangulation".
The authors possess both types of laser scanners, VIVID900 (*Fig.1*) and Cyrax2500 (*Fig.2*), and use whichever more appropriate, considering the object and the purpose of measurement. Generally speaking, VIVID900 is used for smaller objects up to several meters in width, and Cyrax2500 is used for larger objects. The specifications of the scanners are as follows (*Table 1*).

	VIVID900	Cyrax2500
Principle	Triangulation	Time of flight
Laser class	Class2	Class2
Range	0.6-2.5m	1.5-50m, up to 100m
Accuracy	0.2-1.4mm	6mm@50m
Speed	640x480points/2.5sec.	1000 points/sec
Dimension	D 271xW213xH413mm	400x330x430mm
Weight	11kg	20.5kg

Table 1. Specifications of the Two Scanners

There exist cases where obtaining of data becomes a difficulty. For example, when the color of a surface of an object is black, laser beam is absorbed; glass, water, and related materials penetrate laser; and mirrors reflect laser beams in a special non-desirable way.

Moreover, it is greatly influenced by environment. Scanning in rain and snowfall cannot be performed in principle. It is not suitable to use VIVID900 when the sunlight is on an object.

Fig.1 VIVID900

Fig.2 Cyrax2500

2.2 The Measurement Method

In order to create 3D digital data utilizing laser-scanning technology, we start by obtaining a set of 3D position data points called "point clouds". First of all, a laser scanner is set up and fixed in the most desirable place. Measurable area is scanned for several seconds to several 10 minutes (dependent on a type of scanner). Most of the time, it is required to perform laser measurement of the whole object, and that is done by installing a scanner in various positions around the target. The measurements from various directions will result in highly precise 3D data.
In order to obtain data of the whole surface of the object, it is usually necessary to conduct several to dozens, sometimes hundreds of scans from all around the object.
Therefore, the determination of the positioning of a scanner becomes important at measurement work. Not only does it determine the amount of data obtained, but also it has considerable possibility of influencing subsequent work. The shape and size of an object, and other conditions must be considered to judge the most appropriate way for measurement.
It reality, it is very difficult to obtain point clouds for all detailed areas of the object, and some occlusion tend to occur. In order to reduce occlusion to the minimum, it is required to check occlusion by aligning all the point cloud data obtained, as soon as the measurement is over, within the duration of the measurement period, since the result determines whether additional measurement is needed or not.
When an object is large in scale, it might become necessary to construct scaffolds for the scanning activity. Moreover, in order to ease the data processing work that follows, usage of marker targets on an object might become useful.
In laser scanning, it is important to create detailed plans beforehand, with precise knowledge of the location and characteristics of an object well in advance, and also to perform sufficient examination on the method of data processing.

2.3 Data Processing

The quantity of the point cloud data acquired by laser scanning becomes huge, when scanning is performed many times. Although the point cloud data can be processed by using the software attached to a scanner, it does not have sufficient function to create the general-purpose 3D data which can be used for CAD, CG, and VR purposes. Therefore, in order to process data smoothly, it is necessary to use the software designed solely for processing point cloud data. Usually, data processing is performed using exclusive software with special functions, for example, to interpolate, reduce, edit, and polygonize point cloud data.
In using marker targets for measurement, point cloud data is aligned using the coordinate values of targets. However it takes a long time to set and measure targets in this way. On the other hand, alignment of the point cloud data is usually performed by finding the duplicated part of adjoining data. This method can save time and effort, and will lead to shortened alignment processing time. But there is possibility of error accumulation, in this case.
Therefore, in order to keep to minimum the accumulation of errors, making all point cloud data applicable to calculation for the alignment becomes necessary, at the same time.
Both methods are often combined, so that main parts of the objects are aligned by using targets, and the rest of the parts are aligned by finding duplication parts, resulting in efficient and more precise work (*Fig.3*).
Following this process, 3D polygon data is obtained through merging process. It might become necessary to edit the occulusion parts not acquired by scanning, as necessary.

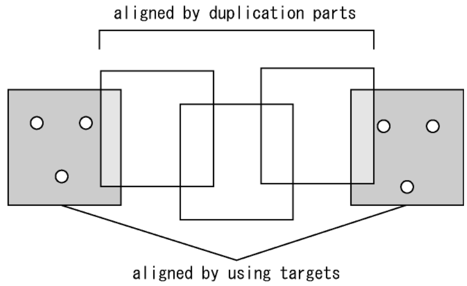

Fig.3 Combined Methods

3. PRACTICAL USE OF 3D DATA

3.1 General

Since the 3D data created can be visualized real time on a computer, the application possibilities expand, from just using it for protection of cultural properties, to utilizing it in a wide variety of fields, including education, research, and multimedia activities. The following items are the practical examples regarding application of laser scanning technology to different areas. Authors would like to evaluate subjects, problems, and so on.

3.2 3D Digital Recording (Uraga Dock)

3.2.1 Purpose: Since Uraga dock (former Uraga Shipyard of Sumitomo Heavy Industries, Ltd.) was established in 1897, many ships and ferries have been built and repaired.
The Uraga dock is one of the important industrial heritages of modernization, symbolizing the town of Uraga for a long period of time.
Even after its close in March 2003, the dock has drawn great attention from both citizens and the local government. The future alternative uses of the property have been discussed, including its reuse as museum, preserving existing facilities. This attention led to the 3D recording of the present Uraga dock using laser-scanning technology.

3.2.2 Work process: In February 2003, the authors made laser scanning (using Cyrax2500) of Dock No. 1, located on the eastern coast of Uraga Bay, the two giant cranes at the side of the dock, and the former head office (*Fig.4*). Maximum laser measurement was performed from the ground level for the given two day period of time. Dock No. 1 and the whole peripheral facilities were scanned.

Fig. 4 Dock No. 1

3.2.3 Application: Not all historic structures can be preserved, and there are many that are lost due to various reasons. Digitised 3D data created by laser scanning the Dock No. 1 area were used to compile the history of Yokosuka City (*Fig.5*). It is very important to record such structures in the best possible ways, to preserve the heritage for future generations as a part of the town's memories. In this case the laser scanning, which had an advantage of speed and accuracy, proved very effective.

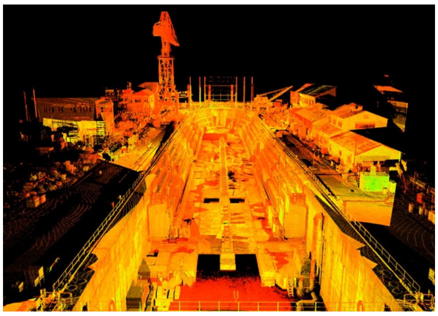

Fig.5 3D Data of Dock No. 1

3.3 Creating 2D Drawings (The Traveler's Beacon in Fukaya City)

3.3.1 Purpose: The Traveler's Beacon in Fukaya City, approximately 4 meters high, was built in 1840 (*Fig.6*). This monument is made of stone but is aging, raising concerns of wear, damage or even collapse with earthquake or typhoon. Blueprint of these historic lantern is necessary as reference material to conduct repair, however, accurate drawings are no longer found today. For this purpose, the authors tried to create drawings from the 3D data acquired by laser scanning.

3.3.2 Work process: Laser scanning (using VIVID900) was completed in one day using the height work vehicle. Processing data and creation of the 3D model took a total of four days.
As the obtained 3D data can be displayed and viewed from any angle, orthogonal and perspective views are easily available.
But it is impossible to extract and draw edges of component joints or uneven surfaces automatically and correctly.
Therefore, the 3D data obtained by laser scanning was displayed from orthogonal view, and after picturizing it, the method of tracing with CAD software was performed (*Fig.7,8*).
Judgement of displayed lines on the 3D model, whether they are joint lines of components, cracks or surface patterns, also proved difficult. Therefore, the parts with difficult recognition were drawn referring to the photograph.

Fig.6 The Traveler's Beacon and the Measurement

Fig.7 3D data of the Traveler's Beacon

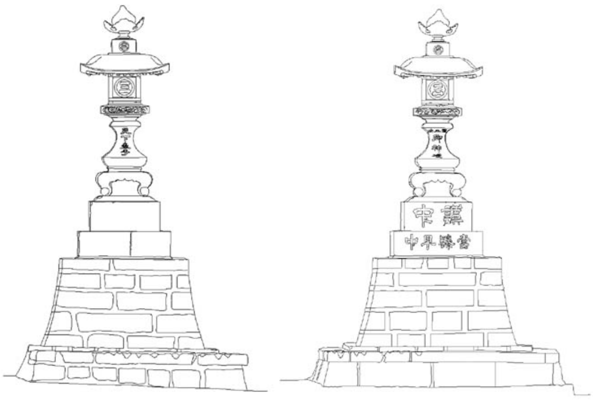

Fig.8 Drawings of the Traveler's Beacon

3.3.3 Results: Manual measurement is inferior to the laser scanning in terms of speed and accuracy. However, manual measurement and drawings made by specialists sometimes becomes inevitable information, depending on who made them for what purpose. In most cases the purpose of laser scanning is to generate 3D data, and not to make 2D drawings. Therefore, in order to meet this purpose of creating 2D drawings, the high accuracy and speed of laser scanning technique may be effective, yet not enough. It is important to increase the reliability of drawings based on advantages of both laser scanning and manual methods.

3.4 Analysis (*Prasat Suor Prat* N1 Tower)

3.4.1 Purpose: The dismantlement and repair construction of *Prasat Suor Prat* N1 Tower in Angkor, Cambodia has been enforced by the JSA (Japanese Government Team for Safeguarding Angkor) since the middle of September 2002 (*Fig.9*). The tower is neighbouring a bank of a pond, and suffers the danger of collapse. The method for repair to be employed is to take apart all components and to repair the broken components and the foundation. Then these components will be assembled and reconstructed according to the state of its founded period. Before the dismantlement, the authors made laser scanning of the tower in order to obtain its 3D digital data, in August 2002. Then using 3D data of the tower, the inclinations of the structure were investigated.

Fig.9 Prasat Suor Prat N1 Tower

3.4.2 Work process: *Prasat Suor Prat* N1 Tower is a large-scale laterite and sandstone made structure with a height of 18m. And there is an air well inside of the structure. In order to get the overall 3D data of the tower, it was necessary to build scaffolds along the exterior and interior walls of the tower (*Fig.10,11*). All measurements (using Cyrax2500) were completed in about two weeks and the 3D data of exterior and interior walls of the tower were obtained. Using 3D data of the tower, the inclinations of the structure were investigated. First, the intersection of the diagonal lines of the structure's four corners of the same layer was identified and assumed to be the central point on the layer. Then, the central points of different layers were connected by lines, and their inclinations were defined as the structure's inclinations (*Fig.12*). In the same way, ups-and-downs of corners on each layer were defined as that of the layer.

Fig.10 Exterior Scaffold

Fig.11 Interior Scaffold

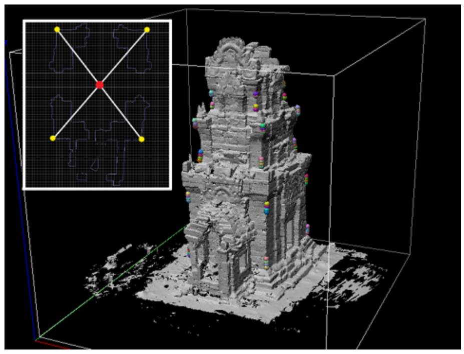

Fig.12 Selected Points on Four Corners

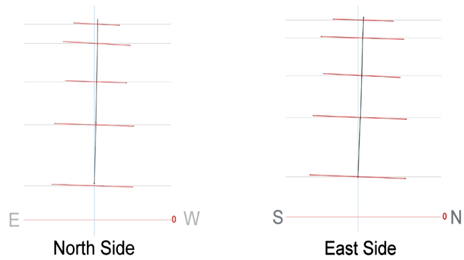

Fig.13 The Inclinations and Ups-and-downs of the Structure

3.4.3 Results: As the result of investigation on the inclinations of 3D model, it was found that the tower is leaning toward northwest direction, which was the same as the finding by the verification of manual measurement conducted beforehand (*Fig.13*). The results of ups-and-downs measurement showed the numerical value mostly interlocked with the inclinations.

It is a valuable result that the same tendency of inclinations and ups-and-downs was found between different methods.

Although it was expected that the numerical value changes with methods, it was proved that laser scanning and manual measurement can supplement each other in order to increase the reliability of accuracy. By making use of advantages of each method, combined use of those methods will bring about even more valuable and useful results.

3.5 Exhibition (12 Divine Generals at Shin Yakushi-ji Temple)

3.5.1 Purpose: The 12 Divine Generals at *Shin Yakushi-ji* temple were created more than 1250 years ago (excluding 1 Divine General), arranged on a giant circular podium around Main Buddha, *Yakushi-Nyorai* (*Fig.14*). As the 12 Divine Generals are made of clay, they have a very weak fault to vibration. One of 12 Divine Generals unfortunately collapsed at time of earthquake in 1854 and the present statue was made in 1931. It is unpredictable when sudden crises may occur to precious cultural properties. Therefore, these statues were recorded as 3D digital models by laser scanner (*Fig.15*). In order arouse interest in general public with regard to laser scanning technology and preservation of cultural properties, the authors made CG animation and created DVD content.

Fig.14 The 12 Divine Generals and Main Buddha

Fig.15 The 12 Divine Generals and Main Buddha (3D Data)

3.5.2 Work process: Laser scanning (using VIVID900) was performed for a total of 8 days from 2001 to 2002, and 3D data of all 13statues were obtained as much as possible. At the same time, surface colour of one Divine General (*Bazara*) was investigated by a specialist, and detailed original colour was completely restored. Texture mapping was most difficult of the whole work. In order to map the textures correctly to unified polygon data created by laser scanning, data must be divided for every part, and texture data must be made to correspond to each. Since the object was complicated in form, the number of texture data increased significantly, and it was not easy to edit or manage them. Therefore, models with clear relevance to corresponding texture data was created beforehand, using modelling software. This resulted in easy editing and managing of texture data. Consequently, it became possible to paste correctly the texture data of the present statue taken by the digital camera on model data (*Fig.16,17*). By replacing present texture data with the restored texture data retouched as a result of investigation, the original coloured model was created (*Fig.18*). Effective and inspiring CG animations were created using this model.

3.5.3 Results: Manual operations were needed to create models with high-resolution, precise-position texture data. Future tasks remain to increase efficiency and to mitigate the labour.

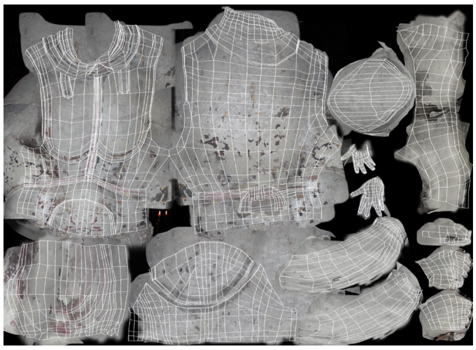

Fig.16 The 12 Divine Generals and Main Buddha

Fig.17 The 12 Divine Generals and Main Buddha

Fig.18 The Original Coloured Model

4. CONCLUSION

Although laser scanning is an excellent technology to obtain highly precise 3D form data of cultural properties at high speed, some subjects and tasks remain to be solved.
It is difficult to complete all work only with the technology of laser scanning, and it is necessary to increase the efficiency of work by introducing and combining other technologies, such as digital photogrammetry.
At present, laser scanners are not developed to scan cultural properties but are developed for other purposes. If demands for creation of 3D digital data for cultural properties grow, it will lead to development of the hardware and software made especially for cultural properties.

Laser scanning should not be regarded solely as the means of recording, but it should be widely applied to the development of 3D digital archives.
It is very important to open and spread technology and information to the general public, by developing effective display methods and user interfaces that can manage to show 3D models including attribute information.

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