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Digital Preservation of a Historical Building – the 3D as-built Scan of Don Nan-Kuan House

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ABSTRACT

This study presents an effort in building archiving for the digital preservation of Chinese architecture. A historical architecture, Don Nan-Kuan House, was scanned. In order to retrieve shapes those are more accurate than traditional manual measurements. A long-range 3D laser scanner was used. Difficulty in measuring as-built forms was solved under the size of a building. The integration of measurements from outdoors and environments was also achieved to clarify the spatial inter-relationship through as-built sections. This research helped us identify the most error-prone measurements done by traditional approach. To represent the special characteristics of as-built 3D building form, the preservation includes the application of as-built data in architecture, the information application of digital data in virtual reality, and the Internet display of large 3D data sets.

Keywords: 3D laser scanner, historical preservation, as-built data.
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1. INTRODUCTION

Most of the historical buildings need long term maintenance. The renovation not only needs correct drawings from previous works, after design stage, the construction data should also be continuously monitored for immediate or post-construction analysis [1-2,6]. Records made by 2D drawings have limitations in conducting a precise description of the geometries allocation in 3D layout, based on discrete manual measurements. Active surface measurement techniques have been used to automatically reconstruct 3D models by joining polygon meshes since 1994 [8]. This technique enables highly accurate measurement of 3D surface. The development in long-range finders has enabled the laser scan of large objects [3]. One distinct example was the Digital Michelangelo Project conducted by the Stanford Computer Graphics Laboratory [4,7], which had scanned the statue of David.

The purpose of this study is to build as-built 3D computer models of a historical building, the Don Nan-Kuan House, to fulfill the need of digital preservation.

2. HISTORY BACKGROUND

The Beipu, which is located in Xinzhu County, is a traditional Hakka settlement in northern part of Taiwan. This small town is full of historical buildings, such as temples, family temple, and old houses. Due to the richness of culture asserts, Beipu is also a famous location for sight-seeing and is always full of tourists during holidays.

The preservation of Hakka culture has drawn public attention in these years. As building preservation is becoming an important issue, most of efforts and resources come from government supports. However, Beipu is a special case that some of the maintenance efforts came from local people and non-

profit institutions. Although most of the historical buildings still function the way they did, new roles are emerging as museum or salon to promote their special characteristics.
Beipu is one of the settlements with the highest density of historical buildings. Xinzhu County Culture Bureau has assisted local culture workers in documentation, survey, and remodeling of these buildings. In order to apply new technology to preservation, the Bureau invited academics as part of task forces to scan the environment and the buildings for future construction or historical references.
One of the buildings belongs to a famous local family named Don Nan-Kuan House (Fig. 1). One important preservation issue is to revitalize the old space with new meanings, in the mean time maintain original appearance or style. Don's House is a typical example which falls within this category. The house was built in 1926 as a private residence. It was a brick house to deliver a modern appearance, which was quite difference from the Chinese style adopted by most of the local residences. The owner was a very famous photographer and won many awards. For over 40 years, Mr. Don had all kinds of subjects included in his portfolio. His legendary career ended in the year he died, 1971. In order to remember his passion to homeland and his contribution to Taiwan photography, this house is changed into a memorial space. In the near future, there'll be gallery, classrooms, and dining place inside. Landscape was renovated in 2008. The interior started remodeling in January 2009 [5] and expect to be finished in the middle of the year.

Fig. 1: The house before and in the middle of exterior renovation.

3. SCAN PROCESS AND DATA
When the scan started in early 2008, there was a garden around Don's house before the renovation had begun. Later the renovation demolished it in a very short period of time, except large trees. The renovation and exterior scan were conducted almost at the same, so the location of scanner had to be planned carefully in order not to intervene machine works. The process can be shown through pictures in which one shows the front gate in original shape and the other shows most part of the columns were disappeared (Fig. 1).
From the life-cycle point of view, the management of a building's information starts from planning, design, construction, maintenance, to demolishing. Every stage of the life cycle should be carefully documented for better construction quality control or for collecting sufficient as-built data. The documentation is very important and should be used for future reference of inspection. For an 80 year-old historical building, a thorough collection of data becomes very meaningful to show the transfer

process from a residence to a space for public, from a home style garden to a designer's landscape. Most important of all, the Don family's contribution can be associated with every change explicitly.

All the scan data are presented in full scale, so measurements can be made in the computer to retrieve the width of walls or the height of roof. The transfer of real world object into virtual world representation enables the collaboration in a broader perspective and the application in all possible manners. For example, different contractors can inspect house dimensions in 3D. Similar to virtual reality interface, all angles can be viewed (Fig. 2) to compare with initial design to check if any modification was made but not recorded yet. The boundary of inspection can be enlarged to have neighborhood buildings (Fig. 3) or the whole street (Fig. 4) included to study skyline. The inspection has higher level of accuracy that the scanner has tolerance at 4 mm/ 50m. With this building width less than 20m, the accuracy is even higher.

The scan data are initially represented as point cloud which is a collection of points for object boundaries. Amount of points also enables a virtually unlimited supply of sampling points for measurements. Because the scans were so intensively made, surface features like curves or holes can be identified. The scan data make it a perfect way to check the smoothness of walls, floors, or ceilings as part of construction quality inspection. Any unexpected surface features can also be identified as precaution to prevent possible design problems. In addition, the scan data were used to generate architectural drawings, such as plan and elevations, in order to communicate with traditional contractors or just for documentation needs. Because all the drawings came from one single scan model, the consistency between different drawings was ensured.

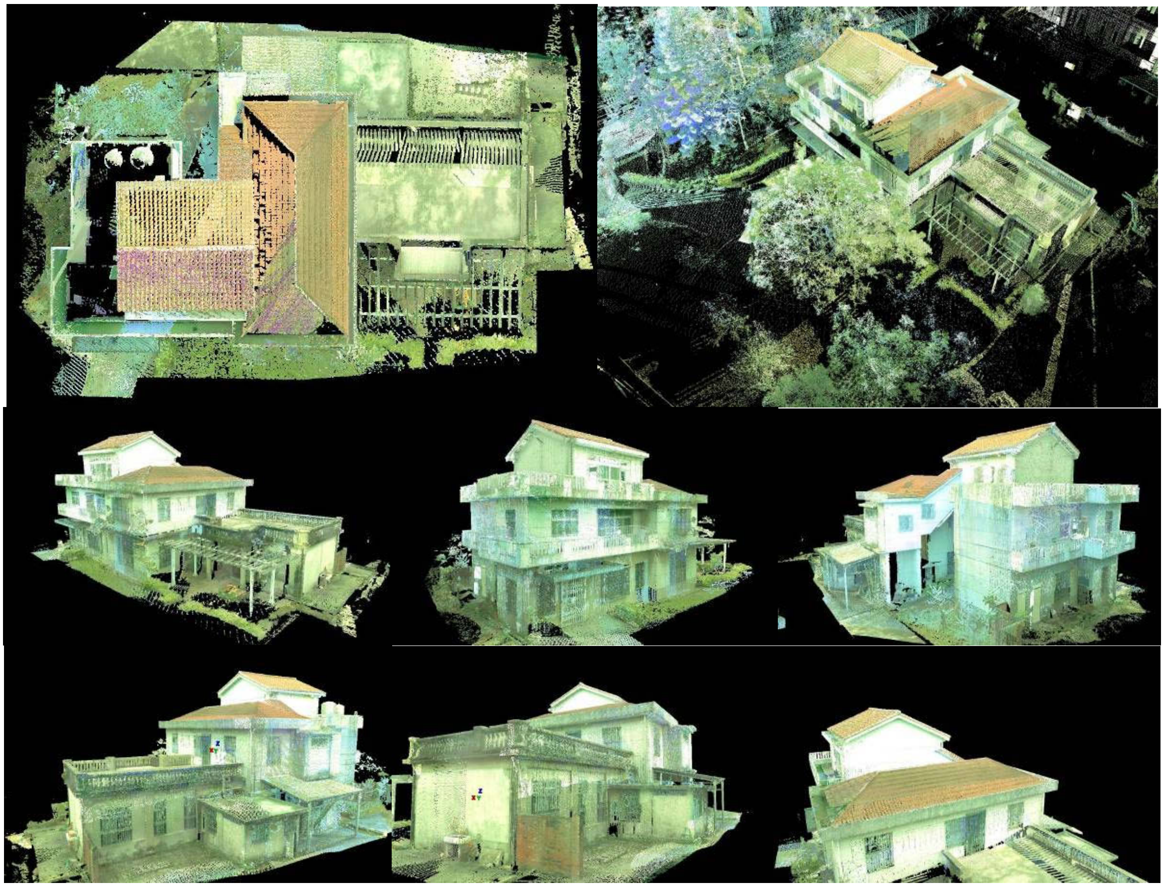

Fig. 2: Site and perspectives presented by point clouds.

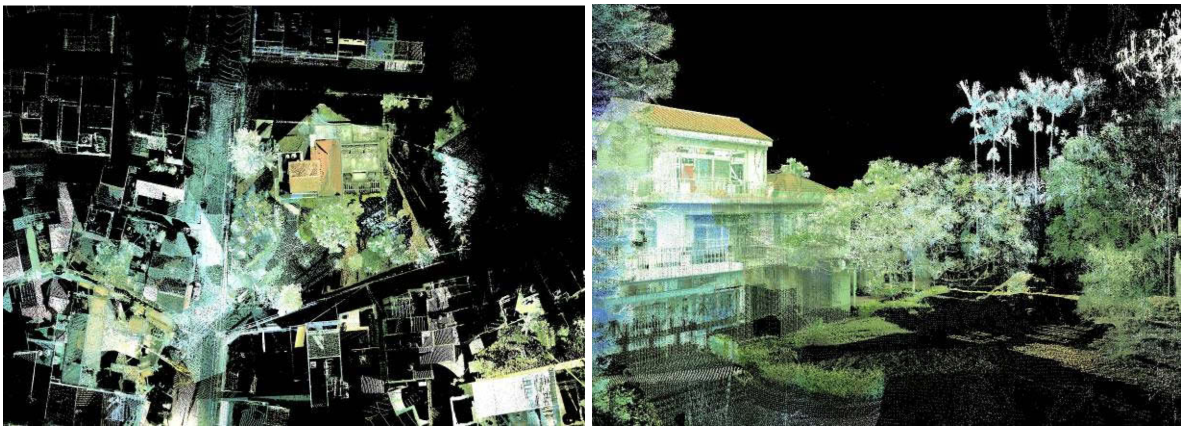

Fig. 3: The entire environment presented by point clouds.

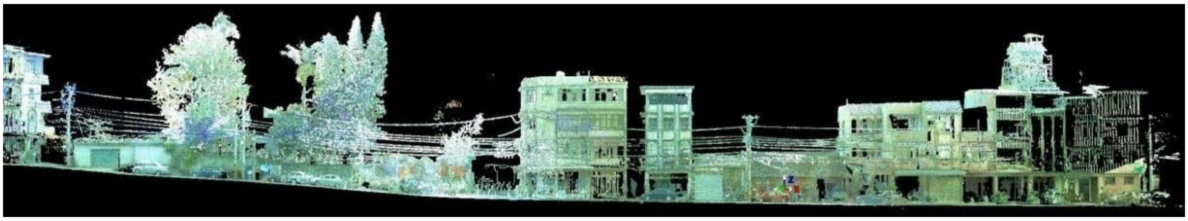

Fig. 4: Elevations of the entire street presented by point clouds.

As the scan field job ended, there were only the building and large trees left. The exterior and interior would be completed in the middle of 2009. A new scan should be planned to have the new interior and exterior included.

The building scan ended with 15,324,415 points and 1,578,500 polygons (Fig. 5) were generated after unwanted data were removed. The number of points would be increased much more when the environment is included. In order to increase the browsing efficiency on internet, web version reduced the number of points and the polygons to 823,112 and 750,000 separately. Both types of data were converted to VRML 2.0, so a user can rotate, translate, and scale the 3D model as wanted. In order to browse the model, plug-ins like COSMO and Cortona can be downloaded as needed.

4. SYSTEM

Instead of using traditional survey data which were retrieved discretely and manually, this study applied a long-range (350 meters) 3D laser scanner, the Cyrax 3000 (also see Fig. 1 left), for continuous data retrieval. The system comes with Cyclone 4.5 software for scanner control and data manipulation. A Class B laser is used and the distance is measured by the differentiation of time the laser spot travels between the scanner and the target. The laser scanner projects laser dots in 360x270 degrees. Actual density can be different in width and height depending on the distance specified between two adjacent dots at a certain distance away from the scanner. The laser dots in a scan or registered scans form a "point cloud" in which each dot indicates the x-, y-, and z-coordinate of the point. A point cloud represents a collection of geometric data, which belongs to an object's surface and therefore can be used to show the appearance of the object. In the database, point clouds are represented in terms of scanworld or scans with exported data contain x-, y-, and z-coordinates and attributes, such as intensity, or color. 3D scan is considered to be non-intrusive technology. Therefore, areas blocked by other objects can only be scanned from other orientations. Scanned point clouds were wrapped into 3D surface models for visualization and the creation of section profiles.

Scans can be made individually or registered into a large project by referring to tie-points or reference points. Each scan has a tolerance of 4mm/50m (2mm/50m in face model). The system comes with a notebook computer to handle the data received on site. Additional data operation was made on a desktop PC. PC and the notebook are upgraded periodically.

Fig. 5: Elevations and perspectives presented by polygon models.

5. SCAN AND REGISTRATION

A "scanworld" is part of a database which contains many scans. A new scanworld is created wherever a new scan location is recorded. The total numbers of points can quickly reach 10 million after registration.

In general, three steps were conducted.

- Pre-scan: planning according to scan resolution, time/duration, human power, weather, circulation paths of machine, availability of power supply, locations of registration points, etc.
- On-site scan: planning for scan locations and reference schemes for registration. On-site scans have two types:
    - Omni scans: scans of larger areas like roofs, foundation, and body from a distance
    - Focus scans: scans of small objects of particular interest
- Post-scan: works like data backup, registration, polygon creation, comparison, drawing production, and Web page design

The file varied from a point cloud (from Cyclone), polygonal model (from Geometric Studio), image-mapped model (from 3DS MAX), to Internet model (from VRML). The size varied from 10 MB to 100 MB.

Geometric Studio was used to create faces from points. Similar functions can also be found in other industrial software supporting reverse engineering. 3D Studio MAX (3DS MAX) is a very popular software for architectural modeling. Many similar applications in the market support image-mapping function and present the same results.

Fig. 6: Drawings generated by tracing point clouds.

6. A REVERSED MODEL CONSTRUCTION PROCESS

A correct shape can facilitate the description of an object in a multi-dimensional relationship, beyond the description of 2D plans, elevations, or sections. The presence of a 3D object reduces the need for line drawings since elevations can be seen from appearance and sections can be retrieved by slicing through the boundary. This is a reversed generation process from 3D to 2D, compared to the traditional drawing production method from 2D to 3D. This process provides highly accurate representations.

The drawing production problem was solved by tracing edges of 3D models directly on a projected plane (Fig. 6). The 3D model can be rotated for better viewing angles. The 3D to 2D production process represents a dramatically different approach from traditional drawing production process. Although a 2D drawing representation of 3D objects were not encouraged, a solution was provided to reduce the errors made from traditional way of tracing on rectified images.

In order to meet the contract requirements, images are shown with the point distance and the number of each scan. Enlarged views were also shown to prove the edges were co-linear along x-, y-, and z-axis (Fig. 7). Traditional scan allocates at least 3 separated reflective targets to be included in scans for registration purpose. The targets are usually installed on tripods, which are difficult to maintain perfect still due to winds or vibrations from vehicles. Small displacement occurs within target clusters will cause tremendous errors on distant buildings, and consequently the wrong relationship between objects. So in field, scans try to collect as many building feature points as targets as possible. The target retrieving process can take up to the half the time of all activities. The digital records of target locations then have to go through a series of registration process to combine all the point clouds of an environment. The final registered model becomes the most important data which record the most updated as-built information. The data can be used by architects, urban planners, or local culture workers for design, inspection, or survey. With the distribution of data on internet in proper format, a user can view point cloud in 360 degrees and even retrieve measurements as needed.

7. LIMITATIONS

Certain limitations still occur to 3D scan technology:

- Scans missed behind obscured parts: Obstruction of laser beams made the measurements behind objects impossible.
- The weight and size of a 3D scanner: The 3D scanner used in this preservation weighs about 10 kg, plus the weight of two batteries. The weight and size are not designed for an easy lift at a place with no elevators. Each trip needs a group of students to move the scanner and associated set of equipment around.
- The open end of the investments for other software: For a budget-concerned firm, the scanner has very high initial investment. The following manipulation of data may need addition investment of 3D software with high-end personal computers.

8. CONCLUSION

A 3D scanner was used for digital preservation of the real world as-built data. Scan data, in terms of point clouds, were used as the main source of geometric information. The data were referred directly to the traditional measuring approach with the proof of accuracy. The digital models will be used as the references for chronological records and lead to discover possible deformation of configuration.

9. ACKNOWLEDGMENTS

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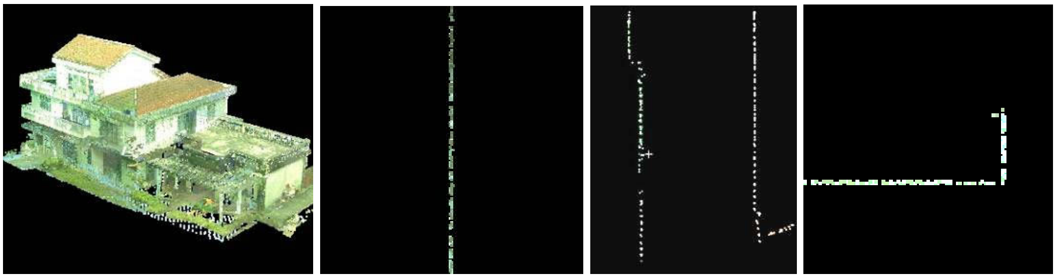

Fig. 7: Co-linear along x-, y-, and z-axis.

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