Characteristics and Utility of 3D Scandata for the Development of Survey Drawings in Wooden Architectural Heritage:
A Comparison of the Raw Survey Data Used in Survey Drawings

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Abstract

3D scandata have become increasingly popular for the preparation of survey drawings in wooden architectural heritage. The objective of this study was to identify the pros and cons and characteristics of 3D scandata. Along with survey record sheets and photographs, 3D scandata are raw survey data that are produced directly on-site. These raw survey data are then further processed in an office in order to be used as survey drawings.

Among those three items, 3D scandata most notably convey the overall shape, location, and dimension of the heritage, while also providing accurate measurements allowing for more accurate survey drawings. However, 3D scandata are somewhat limited in that they do not provide certain information such as colors, materials, and coupling schemes. 3D scandata are obtained in the field, but are usually processed and screened in an office. Some of the 3D scandata are selected to make survey drawings. Therefore, they can serve as useful complements to other types of raw survey data. Furthermore, 3D scandata are beneficial to the tracing of changes in structures, and can also be used for maintenance management and the development of BIMs.

In essence, surveyors are required to perform 3D scanning, as 3D scandata can enhance the accuracy of survey drawings and are utilizable in other valuable ways.

Keywords: wooden architectural heritage; survey drawing; 3D scandata; raw survey data

1. Introduction

In their modern sense, "survey measurements" of wooden architectural heritage have been conducted in Korea by the Japanese since the Colonial period. It was only in 1956 that Koreans took over the role independently. The taking of survey measurements of wooden architectural heritage skyrocketed in 1999 and has been prominent ever since, owing to the significant survey and research accomplishments made in the field.

Despite the relatively long history of survey measurements, the field of "manual survey," a means of developing survey drawings through "survey record sheets (實測記錄帳)" and "photographs", has seen little innovation until recently. Manual surveys recently took a big turn with the incorporation of digital data in survey drawings; the use of three-dimensional (3D) scanners to produce 3D scandata represented an important milestone in the field, as this method of using 3D scandata is rather different from the existing ones (namely, survey record sheets and photographs) and has not yet been standardized. The methods for making survey drawings are therefore currently undergoing significant changes.

3D scandata are one type of raw survey data that can be used to develop survey drawings of wooden architectural heritage buildings. This study seeks to compare and analyze the processes through which three types of raw survey data – including 3D scandata – are acquired, and to examine the characteristics of these raw survey data. A comparison of the different types of raw survey data can help to establish the specific role of 3D scandata in survey drawings and to determine the various methods in which 3D scandata can be effectively utilized. Furthermore, this study may also help to broaden the use of 3D scandata in a wider range of fields.

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(Received April 5, 2015; accepted February 24, 2016)
DOI http://doi.org/10.3130/jaabe.15.161
2. An Overview of the Preparation of Survey Drawings in Wooden Architectural Heritage

2.1 Characteristics of Wooden Architectural Heritage Sites from the Perspective of Survey Drawing Preparation

① Most wooden architectural heritage sites are vast in size. This makes it difficult to view their entire shape and structure at once. Measurements must therefore be taken at multiple locations and heights. For this reason, a number of methods and tools are required to produce the three types of raw survey data. These raw survey data are then turned into various survey drawings.

② Moreover, wooden architectural heritage spaces are broadly divided into interior and exterior spaces, and more specifically, into numerous rooms and spaces under ceilings, and so on. Hence, their measurements must be taken multiple times at various locations and heights.

③ Wooden architectural heritage structures are a combination of different timbers and other materials in various coupling schemes. Therefore, surveyors must examine and understand the coupling schemes, layers, and links with diverse methods of measurements in order to grasp the overall condition of the structure.

④ The preparation of survey drawings of wooden architectural heritage sites requires various pieces of data, including the location, size, shape, color of the materials, structure, and so on. Therefore, several types of data are used even to produce a single survey drawing.

⑤ As wooden architectural heritage sites are immovable, surveys must be conducted on-site. Moreover, the surveys are conducted outdoors, which makes it difficult to create survey drawings directly on-site. Therefore, surveyors collect the raw survey data on-site and integrate some of them into survey drawings back in the office.

2.2 Preparing Preliminary Data

As previously mentioned, surveyors must collect and assemble raw survey data on-site before producing surveys. Raw survey data can be broadly divided into "survey record sheets", "photographs," and "3D scadata."

The raw survey data collected on-site are literally "raw" as they are unprocessed and are not refined in any way. Those data are then brought back to the office to be processed and refined. A survey drawing is produced by gathering selected data from the raw survey data.

As raw survey data have their own characteristics, the raw survey data cannot include all of the information on the "real" architectural heritage site. Moreover, not all of the raw survey data collected on-site can be incorporated into survey drawings of wooden architectural heritage sites. To make survey drawings, only some of the processed and refined data will be selected.

To compensate for these limitations, an accurate survey drawing demands multiple types of raw survey data. The three types of raw survey data mentioned above each have specific traits and values, and those needed will be selected to prepare survey drawings.

2.3 "Manual Surveys" and "Scanning Surveys" Using Scandata

"Manual surveys" have long been the method of choice for the preparation of survey drawings of wooden architectural heritage sites. A "manual survey" refers to a non-digital (i.e., analogue) survey method that uses devices such as tapelines, rulers, water levels, and cameras. Surveyors relying on manual methods first draft a simple diagram of the outer structure and shape. They set a baseline using a tapeline and water level, and record measurements of the distances between the baseline and targets using a ruler. Moreover, they also take photographs. One notable limitation of the manual survey method is that not all of the required measurements can be taken. Surveyors can only obtain data for the parts that they measure.

Digital data has first been utilized with total stations. Total stations emit lasers of certain frequencies to calculate the distance to a target. However, as they can only measure one location, they are inadequate for application to wooden architectural heritage structures and shapes.

Later, 3D scanners emerged. The working mechanisms of 3D scanners are somewhat similar to those of total stations, in that they also utilize the interferences and reflections of emitted frequencies. Unlike total stations, however, 3D scanners can obtain multiple points automatically within a short period of time. An object's 3D spatial information is acquired by forming point clouds from the collected point data.

In other words, 3D scandata can define the perfect overall 3D shape of an object in the form of point clouds.

Currently, the two methods of manual survey and digital data survey are used concurrently. Therefore, it is safe to say that different types of data can be collected. Survey drawings are prepared from the data collected on-site. Those data are called raw survey data.

2.4 The Survey Drawing Production Process

Survey measurements undergo three types of processing, depending on the order and location of the survey.

① Preliminary and on-site survey preparation

Prior to an on-site survey, preparatory steps are needed. Surveyors plan and determine the type and number of survey drawings required for a particular project. Effective survey drawings require accurate raw survey data. Hence, surveyors should research and understand the characteristics of the particular architectural heritage site and its various aspects in order to select the most appropriate surveying equipment and methods. Although this step — i.e.,
choosing the types of raw survey data to be collected — intervenes in the early stages of the survey measurement, it is one of the key steps determining the quality of the subsequent survey drawings.

2 Field survey

In this step, actual survey measurements are taken at the wooden architectural heritage site, yielding various raw survey data. Although the survey methods and equipment selected in the preliminary steps are normally used, in some cases surveyors must adapt to the field conditions and adjust the equipment and methods accordingly.

Furthermore, it is physically impossible to measure all parts or aspects of a wooden architectural heritage structure and shape on-site. Therefore, surveyors must make appropriate decisions as to what parts need to be measured and how to measure them. Therefore, it is possible to adjust the type of raw survey data to be collected as well as its accuracy once in the field.

Owing to the distinctive characteristics of wooden architectural heritage sites, it may be difficult to perform further survey measurements at a later date. Therefore, the first survey must be accurate and thorough. This is also one of the most important steps in ensuring the quality of the subsequent survey drawings, as the latter are prepared based on the field survey measurements.

3 Office work

The raw survey data recorded on-site are brought back to the office for processing, where they are screened to identify the most necessary items. The irrelevant contents are eliminated from further processing. Among the processed and refined data, the most appropriate data are chosen to produce effective survey drawings.

3. Types of Raw Survey Data and Characteristics of 3D Scandata

3.1 Types of Raw Survey Data

As mentioned above, raw survey data are collected and recorded in the field to serve as a basis for the production of survey drawings. Different raw survey data are collected according to the field conditions and survey equipment and methods used.

In the office, the raw survey data collected on-site are processed and refined, and the most appropriate data are selected to be used in the survey drawings. All of the raw survey data are utilized in different ways to inform the survey drawings.

1 Survey record sheets (實測記錄帳)

A survey record sheet is an analogue reference in which the results of the "manual survey" are recorded in the forms of simple drawings, diagrams, and writings. That is, it is a record of certain characteristics — namely the location, shape and size — of the target site as measured with traditional survey equipment and methods.

When measuring and recording locations, shapes, and sizes, surveyors only select the parts that they deem relevant and useful. One advantage of survey record sheets is that they provide information that is only measurable through direct contact, such as the coupling schemes and structures, materials, and surface finishes, which are difficult to obtain through other measurement methods. Surveyors can confirm this information through visual or tactile contact, allowing for the survey of parts that are not visible.

On the other hand, one of the downsides of survey record sheets is that as surveyors subjectively choose which parts to measure, information about other, non-selected parts cannot be derived.

Table 1. Survey Record Sheet Sample
Therefore, with this particular type of raw survey data, the importance of fieldwork outstrips that of office work.

Photographs

Photographs are products of "manual surveys." Surveyors record information, including the target's relative shape, size, location, and color, using a camera. The use of photographs as sources of digital data for survey measurements has recently increased.1

Similarly to survey record sheets, photographs require surveyors to make decisions while in the field. As photographs depict a certain angle of a photographed object, surveyors need to decide which parts to include in the frame. After they are taken on-site, photographs are brought back to the office to identify and select the necessary information to be included in the survey drawings.

One of the merits of photographs as raw survey data is that they are a relatively accurate source of information about the target's shape, location, and color. In particular, the provision of color information may be one of the most beneficial aspects of photographs, as other types of raw survey data cannot convey this information. On the other hand, although photographs provide information about the relative size and location, they do not offer accurate measurements. Moreover, they can only capture the parts that are recorded by the camera; therefore, they do not provide information about the parts that are not visible or those that are difficult to capture with a camera, such as coupling schemes.

In summary, photographs are highly beneficial in providing color information. In their case, field and office work are equally essential. Therefore, traditional manual surveying methods use both survey record sheets and photographs, as the two provide complementary data.

Table 2. Photographic Samples
(The Main Hall of HeungChun-Sa in Seoul)

<table>
<thead>
<tr>
<th>Front view</th>
<th>Side view</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column details 1</td>
<td>Column details 2</td>
</tr>
</tbody>
</table>

3D scandata

Table 3. 3D Scandata Sample
(The Main Hall of HeungChun-Sa in Seoul)

<table>
<thead>
<tr>
<th>Longitudinal view</th>
<th>Cross-sectional view</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor plan</td>
<td></td>
</tr>
<tr>
<td>Column details 1</td>
<td>Column details 2</td>
</tr>
<tr>
<td>Column details 3</td>
<td></td>
</tr>
</tbody>
</table>
3D scandata are a type of digital raw survey data that are not used in traditional "manual surveys." They are the combination of all the points of a wooden architectural heritage site as acquired with a 3D scanner. One advantage of using 3D scandata is that it allows to take exact measurements of the location, shape, and size of all parts of an architectural structure. However useful, 3D scandata nevertheless present limitations in that they do not provide color information. Furthermore, more detailed information that may be difficult to identify with visual cues only – such as coupling schemes or materials used – do not appear on 3D scandata.

Unlike other types of raw survey data, 3D scandata do not require surveyors to determine what sections or parts to measure. They can scan the entire shape of the heritage building instead. Due to the vast scales and divided spaces of wooden architectural heritage sites, the point data for the entire shape cannot be obtained from a single location. Hence, the scanner is moved to different locations to compile a set of point data for the entire shape.

Once the 3D point data have been generated by the scanners, they are brought back to the office for further processing, adjustments, and de-noising. The processed point data are then compiled into one file and are screened to extract the most appropriate information to be included in the survey drawings.

In summary, at the architectural heritage site, the objective is to obtain scandata for the entire shape of interest by performing a number of scans from various locations. Office work is relatively more significant in the case of 3D scandata, as the unprocessed mix of point data that have been acquired in the field must be combined and screened to select the most relevant data for the survey drawings.

3.2 Comparative Characteristics of Scandata

Survey contents and accuracy

3D scandata clearly have a competitive edge over other types of raw data. While survey record sheets only provide measurements for the parts selected by the surveyors, 3D scandata offer measurements of the shape, location, and size of the entire structure without leaving gaps. Moreover, 3D scandata are significantly more accurate than the data collected with manual surveys. Although 3D scandata do not convey color information (while photographs do), this type of data displays accurate measurements that cannot be recorded in photographs.

In essence, the strengths of 3D scandata include the accuracy of the location, shape, and size measurements, and the comprehensiveness of the data provided. Nevertheless, as the mechanism underlying 3D scanning involves the use of lasers, 3D scandata do not reveal information about the coupling status, materials, and colors, and are only limited to the parts accessible to the lasers.

Table 5. Characteristics of Raw Survey-Data with Comparison

<table>
<thead>
<tr>
<th>Category</th>
<th>Survey Record Sheet</th>
<th>Photographs</th>
<th>3D Scandata</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data type</td>
<td>Manual survey</td>
<td>Manual Survey</td>
<td>Scanning</td>
</tr>
<tr>
<td>Working Type</td>
<td>Preliminary survey, Field survey</td>
<td>Field survey, Office work</td>
<td>Office work</td>
</tr>
<tr>
<td>Selection/Decision</td>
<td>Field</td>
<td>Field, Office</td>
<td>Office</td>
</tr>
<tr>
<td>Subjects of measurement</td>
<td>Shape, location, material, surface finish, coupling condition, etc. of selected parts (especially invisible parts)</td>
<td>Color, Shape within an angle, relative location, size</td>
<td>Shape with accurate measurements, location, size</td>
</tr>
</tbody>
</table>
On the other hand, survey record sheets are made only after the surveyor carefully deliberates over the final outcome of the survey drawings, choosing the most appropriate survey equipment and method to achieve that outcome in the field. The decisions about which parts to include in the record sheet are made in the field, and the office work merely involves the reorganization and mapping out of the survey record sheet data. Therefore, the office work has to be performed by the field surveyor or someone familiar enough with the surveyor's survey-recording system to grasp the recording methods and intentions fully.

Similarly, photographs also require on-site decisions from surveyors to select the most relevant sections of the structures to include in the camera frame. Those photographs are further screened in the office to trim out the irrelevant parts, and only the most appropriate sections are used in the final survey drawings. Hence, photographs are a type of raw survey data that necessitate decision-making and selection processes both in the field and in the office.

4. Utilization characteristics

As previously mentioned, surveyors only need to engage in minimal decision-making to generate 3D scandata in the field, as most of the data-processing is performed in the office. Moreover, 3D scandata hold information about the accurate shapes, sizes, and locations of entire architectural heritage sites. The extent of the information provided by 3D scandata far surpasses that of other data types, rendering it useful as an overall source of information for various survey drawings beyond the one initially planned.

By contrast, survey record sheets can only be used in the initial survey drawings planned at the preliminary stage or during field work, as all of the information it contains is selected based on the needs of the particular survey drawing. Furthermore, it is very difficult for someone other than the surveyor to grasp the information contained in the record sheet precisely. Photographs also carry limitations in that only the sections included in the camera frame can be exploited for other survey drawings.

In light of this, 3D scanning provides additional benefits as it compensates for the shortcomings of survey record sheets and photographs.

5. Digital data characteristics

3D scandata take the form of digital data, while survey record sheets are analogue data that are recorded on paper. Photographs can be both, although the digital format has become more common in recent years.

The most notable characteristic of digital data, reusability, applies to 3D scandata as well. 3D scandata are not merely "raw" data that depict the entire shape of an architectural heritage site. They are not tainted by surveyors' decisions and selections, and are therefore available for use by other people in a variety of different ways.

Despite these advantages, 3D scandata however are large files that are difficult to process. They require professional personnel, costly computers and technological equipment, and several professional programs. In other words, they are financially burdensome.

Thus, survey record sheets are paper records of information selected by a surveyor, which undermines their utility to someone else at a later time. Photographs present similar limitations due to their inherent characteristics. The traditional "manual survey" methods also have relatively low utilization potential, as they require the same person to perform the field survey and the office work to prepare survey drawings.

4. Utility of 3D Scandata

4.1 3D Scandata for the Development of Survey Drawings

1) 3D scandata are extremely useful for this type of drawing, as they present accurate numerical measurements of the overall shapes and locations of the site's sections.

2) 3D scandata are also convenient for office work, as they complement survey record sheets and photographs. That is, as they provide an accurate representation of the survey target on computer, it is possible to measure the shape without actually being at the site.

3) Each type of raw survey data has its distinct characteristics and uses; hence, a combination of several types of raw survey data is required to prepare a single survey drawing. However, a blended mixture of different data may cripple the accuracy of the overall data. Therefore, it is imperative to ascertain the accuracy of the final survey drawing. This can be done with 3D scandata.

4.2 Potential Utilization of 3D Scandata After Completion of the Survey

As mentioned above, 3D scandata are mostly processed in the office rather than in the field. As minimal decision-making and selection are involved in the field, they are fit for use in other areas as needed.

In particular, 3D scandata may be useful in various areas, including safety management, maintenance work, and tourism promotion.

1) Displacement measurement

The substructures within an overall wooden architectural heritage structure are not permanent; over time, they are bound to move and undergo changes. Thus far, those changes have rarely been studied. As 3D scandata represent precise measurements of each section of the structure, the taking of a new set of 3D scandata at a later time may allow surveyors to compare two data sets and to trace the changes in the shape or location of the structure over time. Understanding the changes in building components may represent a step toward the study and design of architectural heritage sites.
remedies to mitigate changes in wooden architectural heritage structures.

2) Preservation

3D scandata provide accurate measurements of the target. This information is conducive to preservation work in the event of any damage to wooden architectural heritage structures. Moreover, if 3D scandata are available, each component of the building can be manufactured using CAD/CAM processes, allowing for more precise replacement and maintenance work.

3) Building Information Modeling (BIM) data

3D scandata convey information about the shapes and locations of many components of a building. The data for each component of the building can be separated and run through a BIM program to generate digital representations of the components. A BIM system based on 3D scandata can generate BIM data that closely resembles the actual physical structures of the architectural heritage building. Hence, 3D scandata can be regarded as the most effective type of raw survey data for BIM. Moreover, the establishment of a BIM system effectively assists in the preparation of survey drawings.

5. Conclusion

This study analyzed the characteristics of 3D scandata from the standpoint of the production of survey drawings. By comparing 3D scandata with other types of raw survey data, this study identified the unique merits of 3D scandata and suggested measures to maximize their utility.

3D scandata are produced by 3D scanners that emit lasers to generate accurate measurements of targets, and translate them into digital representations. They convey information pertaining to the overall shape, location, and size of the target and, most importantly, its measurements. However, 3D scandata do not provide information such as the color, material, surface finish, and coupling scheme.

3D scandata complement other raw survey data, allowing for the production of more accurate survey drawings.

Surveyors scan the target structure to acquire 3D scandata in the field, and the acquired data are processed in the office so as to compile a number of data sets into a single file. Surveyors then screen the refined scandata to select the essential information to be used in the final survey drawing.

Thus, 3D scandata are a necessary but insufficient tool for survey drawing. In fact, all types of raw survey data are insufficient on their own. Nevertheless, 3D scanning offers great potential to be used in other areas, such as to complement other raw survey data, to trace the displacement of structures, for maintenance management, and for BIM.

For those reasons, the use of 3D scandata is clearly necessary to boost the accuracy of survey drawings and to support other functions.

This study aimed to examine the specific properties of 3D scanning, whose use is increasingly common in surveys of wooden architectural heritage sites, and to propose measures for their effective utilization. The author hopes that future studies will shed more light on the usefulness and techniques of 3D scanning for the development of survey drawings of wooden architectural heritage sites.

Acknowledgement

This work was supported by the Sun Moon University Research Grant of 2015.

Notes

1) Until now, research has focused on the technical aspects of 3D scanning rather than on its theoretical aspects. For examples, see references 6, 7, and 8.
4) Each 3D scanner manufacturer uses a different program, e.g. Cyclone and Cloudworx for Leica, Scene for Faro, Trident-3D for Trimble, and so on.

References