

CHENGMIN ZHOU *et al.*: A STUDY ON THREE DIMENSIONAL SCANNING AND MAPPING . . .

A Study on Three Dimensional Scanning and Mapping and Implementation Key Technology of Wenge Bench Parts

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Abstract —The paper mainly applies three-dimensional (3D) scanners to carry out mapping for traditional furniture parts, making a systematic study on the parts size, recognising the application potential of 3D furniture mapping. In the course of the study, firstly an historic wenge bench is selected with its components acting as measurable objects, and then secondly we carry out specific work for the experimental study. Combined with advanced 3D scanning equipment and the measuring process study, details are described using 3D mapping methods, mapping key technologies to acquire a series of data through the mapping experiment on the antique furniture. The purpose of this research is to enable furniture design to be better integrated with advanced technologies; the study and design of traditional furniture can be further developed using high-tech means. It can provide basic design parameters and image data to inform digital furniture development and design systems.

Key words - 3D mapping, historic furniture, data processing, furniture design

I. OVERVIEW AND APPLICATIONS OF FURNITURE 3D MAPPING

A. Definition of Furniture 3D Mapping

3D mapping of furniture refers to the application of 3D scanning technology to measure, acquire and simulate the furniture's shape, size, space and the properties in order to make available processing data obtained from acquired data, information and results^[1].

B. Furniture 3D Mapping Process

Simply speaking, the course of 3D scanning and processing for furniture is to scan three-dimensional objects like furniture parts and acquire the point cloud data on the object surface; this data will become CAD 3D data after software processing.

The specific process is shown below(Fig. 1).

C. The Application Range and Prospect of Mapping

Nowadays in domestic China, 3D mapping technology is most widely used in relief applications of traditional furniture decoration as well as for virtual display and digital customization of furniture sales^[2]. In addition, there are also applications which provide reference for furniture appreciation and designers^[3]. For example, innovative items like Accelerated Parallel Processing application of *Chinese Antique Furniture, an APP application*, launched by the Digital Media studio of Central Academy of Fine Arts together with Lemonista Design, combines traditional Chinese furniture parts and mapping methods to successfully produce an application software integrated with popular science, entertainment and academic research based on high-tech software development means. This software also conforms to contemporary aesthetic and technological levels.

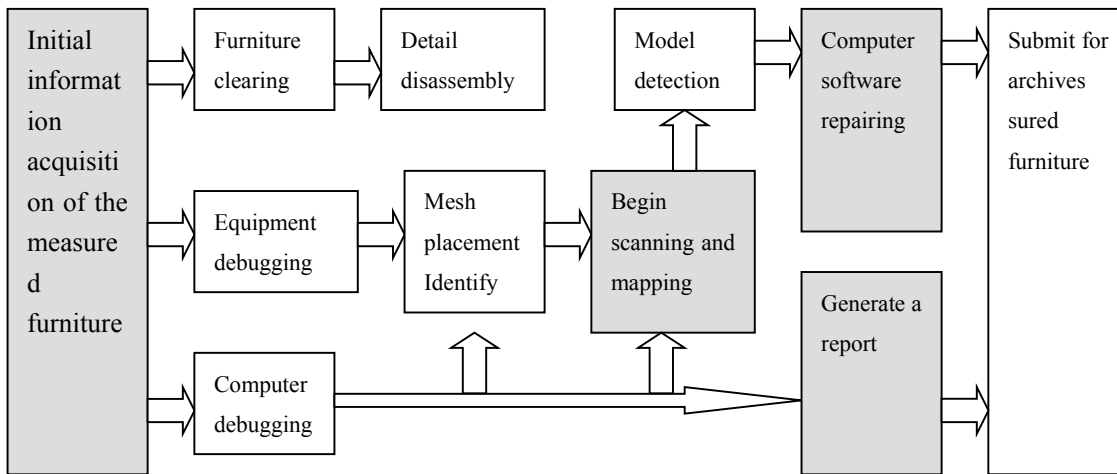


Fig.1 Furniture dimensional scanning mapping process

D. Selection of furniture for study

Explain why we have selected the wenge bench. Because it is a good example of furniture that will benefit from the mapping process as it has some complex components which are problematic/ challenging to draw or record with standard photography, etc. Also it is a good exemplar of Chinese historic furniture. This bench also has provenance and we therefore know it is from a reliable collection/museum...



Fig.2 The Bench photo



Fig.3 The top face of Bench

II. INITIAL ANALYSIS OF THE WENGE BENCH'S PARTS AND STRUCTURE

Basic dimensions of the wenge bench after measurement: Length: 120mm Width: 120 mm Height: 200 mm. The bench's face is enclosed with table border; the 'ice-plate' edge is wide above and narrow below with a high waist. On the waist, there is relief carving in Guaizi design and begonia-shaped prescribed decoration. The leg is an extended type, and there is relief carving in a Ruyi cloud design on the four corners at the top. There is hollowed-out Duobao design on the board. There is a small dragon design on the board. Evaginable horse-hoof foot is located on the Tuoni (a wooden-frame supporting legs) and there are legs under the four bottom feet.

III. DATA ACQUISITION OF WENGE BENCH PARTS

A. Overview and Principles of Data Acquisition

Data acquisition is actually sample piece surface digitisation. It refers to adopting a specific measuring method and equipment to measure geometric co-ordinates of specific sets of points on the surface of the material of the sample piece to acquire geometric information about the surface. [4] With this captured information, improvement and making of the curved surface can occur.

It is important that an efficient and high-precision data acquisition system is employed. This will allow any reconstruction to be precise, which is critical to achieve an accurate CAD model. Firstly, to be able to achieve precision the object's mathematical geometrical characteristics must be recorded. Secondly, the periphery, edge lines and places that have a larger curvature change must be measured to capture the object's shape-surface

characteristics. For places with a more complex curved surface structure, an increase in the number of co-ordinates must be applied .

B. Data Acquisition of Wenge Bench

The mapping of the components is compared against data acquisition of parts on the basis of existing physical models. [5] Compared to simple modeling designs, the accuracy and completeness of the data are more complex. In this example the mapping data of component parts will have corresponding real data for comparison and calibration.

1) The Data Acquisition Instrument of CREAFORM Laser Scanner

The furniture relief carving 3D scanner is a high-tech piece of equipment connected to a CNC carving machine. It is mainly used to scan relief carvings and three-dimensional patterns for digitisation, to provide digital processing files for CNC carving equipment and CNC routing equipment. [6]

1. Equipment description

The scanning equipment used is a MetraSCAN™ optical CMM scanner manufactured by the Canadian CREAFORM Company, having scanning accuracy of 0.2mm. The Armless handheld MetraSCAN™ 3D scanner system (supplied by Creaform Co., Ltd.) and C-Track™ 780 dual-camera sensor have formed a unique combination to make sure that the most accurate measuring values can be made in the laboratory and workplace. Meanwhile, with the C-Track™ dynamic reference model, similar systems can be locked up to the measured parts one by one so that the parts can maintain alignment during the entire process. It has an auto-alignment function; manual operation is not needed any longer in alignment, greatly reducing errors from the source.

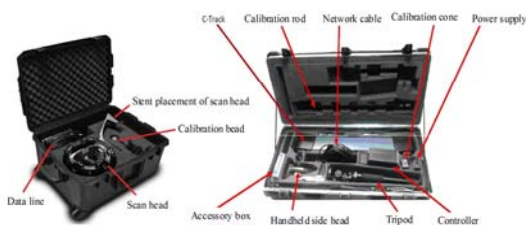


Fig.4 Three-dimensional scanner device

2. Equipment installation

Firstly, set up the tripod, fix the C-Track™ onto the tripod, adjust its scanning direction and range, and observe the distance and angle between C-Track™ and the measured object.

Secondly, connection among parts: 1. Connect the line on one side of C-Track™ 2. Connect C-Track™ to controller 3. Connect data line to the scan head 4. Connect the data line of scan head to controller 5. Connect the power line of controller 6. Connect the network cable to controller and computer 7. Startup controller and begin preheating 8. Startup software, if the computer IP is changed, firstly operate IP address configuration, and then the connection is made.



Fig.5 Installing C-Track™



Fig.6 Connections

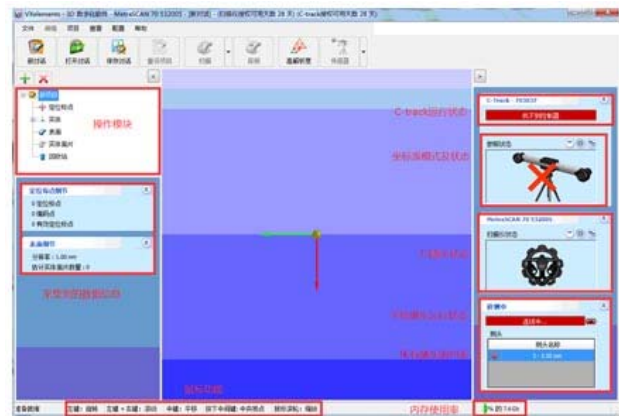


Fig.7 Mapping software interface

3. Software interface, startup software interface, open operator interface, and make interface debugging. As shown in Fig. 7.

4. Equipment calibration

(1) C-Track™ calibration:

When all connections are complete, wait until the

C-Track™ is stable, and all preparation work will be ready in one minute, then begin to calibrate the instrument. The calibration should be conducted once a month according to software's prompts. Select C-Track™ command, calibrate C-Track™ 1-2.5 meters away from C-Track™. There are three directions in the calibration process. The point on the calibration rod shall face C-Track™. It is troublesome to pay attention to distance and height, and grasp the calibration process. Fig.8 is the calibrated picture according to the computer prompts.

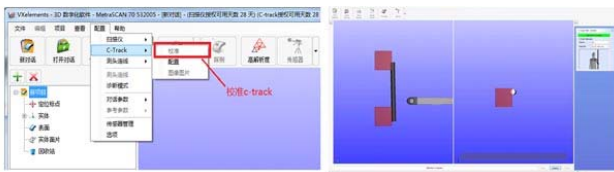


Fig.8 Correction Tips

(2) The scan head calibration:

The scan head aligns to the center of calibration bead for scanning until colours in all areas become dark green, and the software will automatically calculate the calibration result, and only then click Optimization and Save. As shown in Fig. 9:

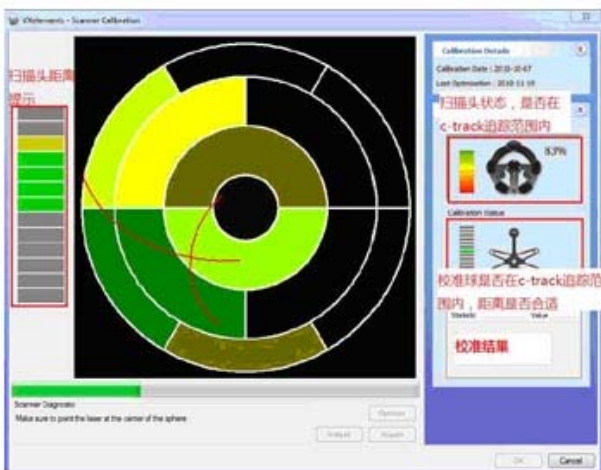


Fig.9 Scan head correction

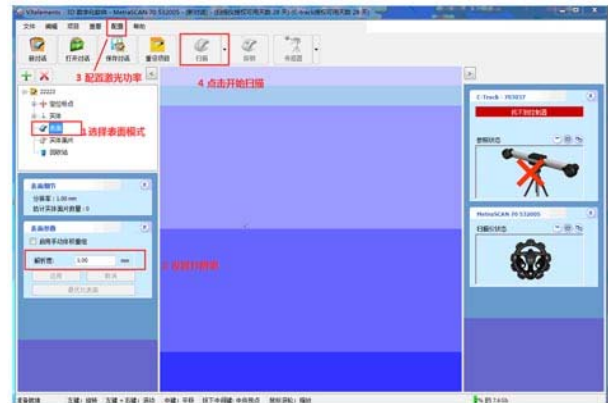


Fig.10 Location makes it a good debugging parts tracking in the range of c-track

2) Scanning Process

After completing the equipment's preheating and calibration, the object to be scanned is placed within the scope of the C-Track™ reception, and then adjustments can be made to the object's height (if required). Whether the object is placed appropriately or not decides whether the position of 3D model showing on the computer interface meets requirements; if the position is too low or too high, the model formed after scanning will be likely to be located below or above the co-ordinate axis; if the position is too far away or too close to the receiver, the model formed after scanning will be likely too large or too small for the co-ordinate. Therefore, prior to the formal scanning, it is very important that the position of the object can optimally present the authenticity of the object. As shown in Fig. 9.

After the model is positioned, in order to comprehensively scan the model, it is prudent to check its stability and height. Use the armless scanner; whether it can scan completely or not largely depends on the operator's ability. Use infrared ray on the scan head and gradually scan each position aligning the scanned object.

As there are certain limitations in the C-Track™ positioning, the scanned object shall not be moved arbitrarily during the scanning process, otherwise the object's co-ordinates may change and the scanning will be suspended. When scanning is started again, the whole process will be repeated. The previous model will be

automatically deleted if it is not saved. Instead, what we use is an auto scaling model. It's size is less than one third of the size of the scan head. Thus the difficulty in scanning increases. As the operation is gradually improved, the model that we acquire in scanning is also increasingly complete. After the scanned model is saved to be in .stl format, continue scanning the next section.

In the bench's scanning process, mainly scan the bench's knee and carving at the waisted section; compared to other objects that have been previously scanned such as an Eight Immortals table, the bench is longer in shape and simpler in structure. It is mainly characterized by the legs made of a carved and polished piece of wood. The fluent curved styling reflects the highly skilled craft of Chinese antique furniture. Combined with the scan head and C-Track™, the effectiveness of scanning is greatly improved on traditional scanning techniques. It only takes several minutes to completely represent a bench model using this scanning process. Fig.11-12 shows the model acquired through initial scanning of the bench as seen on the scanning interface.



Fig.11 Scanning interface



Fig.12 Scanning bench model

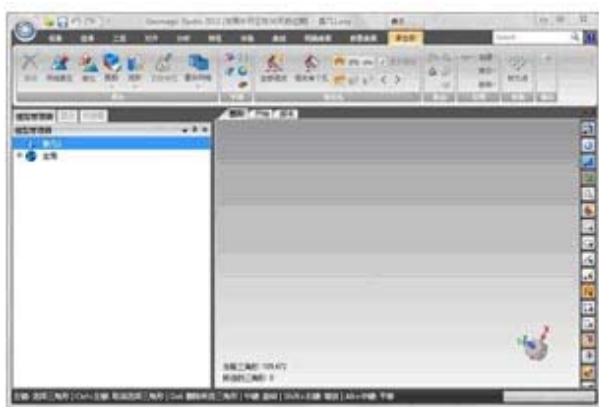


Fig.13 Interface of Geomagic Studio 2013

IV. PROCESSING THE SCANNING DATA OF BENCH

A. Surveying and mapping processing software Geomagic Studio

Geomagic Studio can generate accurate digital models in accordance with any physical component automatically. It is the first choice of automation reverse engineering software around the world, Geomagic Studio also provides the emerging application with ideal choices, such as mass production of customized devices, custom-made production mode and the automatic remake of originals [7]. Figure 13 is the interface of operating software used in this experiment.

B. Processing the data of facets of various components and parts of bench

1) Overview of data processing

Data processing is a key link of surveying and the mapping process of components and parts, which decides that whether the follow-up reconstruction process of model can proceed expediently and accurately. The work of data processing covers data filtering and smoothing, multi-view data integrating and aligning, as well as data reduction. Processing the data prior to the exact reconstruction of the model as well as obtaining complete and accurate data so as to prepare for the follow-up reconstruction of the model [8].

2) The data processing procedure of components and parts

(1) Import the scanning files into Geomagic Studio

Open the DXF scanning data outputted from the computer in the model room by using Geomagic Studio (as shown in Figure 14). These data show crude and irregular curved facets,. The user needs to select them, reduce the noise, repair holes, edit the edges and so on, so as to obtain desired facets.

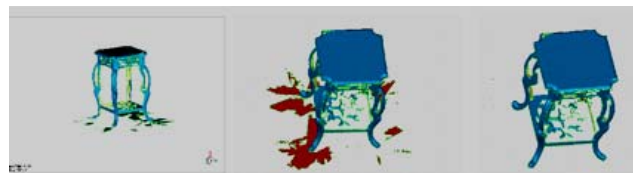


Fig.14 Interface of Geomagic Studio 2013. Fig.15 Delete selected facets

(2) In the polygon phase, process the scanned data. Delete redundant facets and repair the holes. As is shown in Figure 15. This is equivalent to removal of flashing in casting followed by chasing, de-nibbing and general refinement of the cast object.

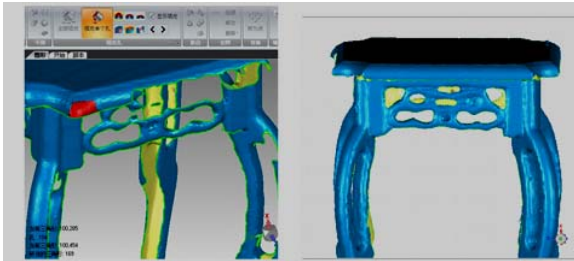


Fig.16 Interface of Geomagic Studio 2013. Fig.17 Delete selected facets

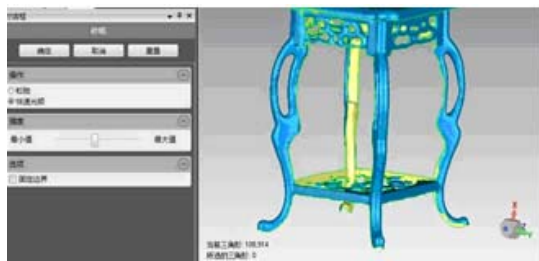


Fig.18 Trim legs

Choose polygons to fill any single holes, which includes three types of filling, namely, hole filling in closed figures, the filling of marginal holes and the bridging between complex holes. Users can choose types according to the different filling of various parts of the model. Figure 16 shows the filling of a marginal hole. If users want to fill the sideward part with larger holes, they can choose bridging filling firstly, and then conduct the hole filling in the closed figures after building closed holes. Figure 17 shows the effect of bridging filling. After that, use filling and abrasive paper function to trim curving legs, just as shown in Figure 18.

The legs of the bench are the most typical parts of the whole model, the integrity of whose model scanning and repairing is very important. During the repairing process, it would be best to repair by reference to the profile pictures of the original model. Firstly, fill the fractured part through hole filling command, and then fill the internal empty holes

that cannot be scanned after improving external contour. Finally, construct qualified facets that meet the rate of curving of legs by utilizing network repair function found in Geomagic studio.

V. MODEL RECONSTRUCTION

A. Overview of model reconstruction

The ultimate purpose of the surveying and scanning of components and parts of furniture is to combine, reconstruct and deepen the furniture model after understanding the structure of every component and part, that is to say, reconstruct the three-dimensional CAD model of the physical sample, which shall not only be similar to the original sample in some aspects, but also shall reflect the structure among components of the sample. Although some positive results have been achieved, it is still a difficult and complex problem to construct a complete CAD model with high compatibility and achieving a high level of quality. This is because some of the parts encountered are difficult to measure, such as internal cavities, which cannot be obtained through scanning. When being imported into Geomagic, these parts without being measured cannot generate a curved surface, and the modeling function of Geomagic software is deficient, so it can only make the scanned point clouds generate curved surfaces. In addition, Geomagic software can only obtain a surface model after the completion of the fitting of a curved surface, which is short of topological relation of the physical entity with the adjacent surface and edge^[9].

During the process of reassembling the original CAD model of the product through 3D surveying and

mapping scanning technique, the simple use of a specific generation type of curved surface cannot complete the reconstruction of the whole model. An appropriate generation method of curved surface should be selected in accordance with the geometric features of the product's appearance to obtain a better geometric model of the original product, so as to satisfy the geometric features of the products appearance.

B. The modeling process of components and parts

During the remodeling process, the product will be saved as *.3ds file format model and then be imported into 3DMax software, which will be split into components and parts in 3D.

The software programme needs to accept and reject some operations during this split process. For example, the legs, because of the symmetrical structure of the bench, only need to be captured and filled up for one leg during the scanning and repairing process, which applies to all other comparable components. Therefore, after having imported into 3D, repetitivel components may be deleted. A complete model can be obtained after choosing and implementing the array command during the final reconstruction process.

Add tenons to every component according to the basic structure of bench. (As is shown in Figure 19 and 20.) Ensure that the mortise and tenon are proportional to the component.



Fig.19 Add mortise to legs. Fig.20 Add mortise to side carved panels

After constructing all parts, assemble them on the basis of the correct proportion. Next, use Keyshot (an interactive ray tracing and universal light rendering program, which can produce 3D rendering image that is as real as a photo without a complex setting) to render and modify. The completed bench model is now formed. As is shown in Figure Fig.21 and Fig.22.



Fig.21 Exploded view of the bench. Fig.22 Assembly view of the bench

VI. CREATION OF DATA TABLE

A. Principles of data compilation

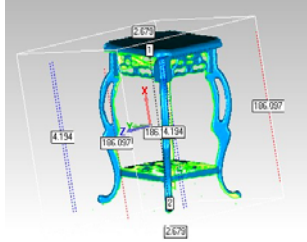
Data compilation refers to the data which is held in the database ensuring that it is organised so that it can be retrieved quickly and accurately in order to provide a complete set of data required to construct the models. The data compiling process is made up of data acquisition, data sorting and data storage, that is to say, collecting dispersed relevant information, which is then arranged in the correct order, according to category, letter of words reflecting information content and stroke number.^[10]

Compiled data should contain reliable information, which can be disseminated via the Internet and other open source or closed information platforms. The data sorting of information system shall be conducted from the perspective of the user application. This is based on the principle of employing the results of data sorting to provide users with a valid and comprehensive service.

B. Analyze experimental data by utilizing Excel

Sort and import the data obtained from scanning, surveying and mapping into excel form to create a visual data table of the bench.

TABLE 1. DATA TABLE OF THE BENCH

Part name	Length*width*height (unit: cm)	Remarks	Legend
Surface of the bench	12*12*1	The type of joggle joint with legs: right-angle tenon	
Leg	19*2.5*1	The type of joggle joint with surface and lateral sides: embracing-shoulder tenon	
Side carved panel	8*3*0.8	Its joint with legs and surface: right-angle tenon	
Carved panel of pedestal	9.5*9.5*0.8	Its joint with legs: right-angle tenon	
The measured object is the bench model made according to specific proportion (overall dimensions: 12*10*20)			

VII. CONCLUSION

As illustrated in this research this advanced three-dimensional surveying and mapping technique can produce a series of data, and re-transform real objects into three-dimensional virtual models by using the said software. Additionally, the modeling techniques adopted can provide more details about the structure and shape characteristics of classical furniture. Three-dimensional surveying and mapping techniques are significant for the research of classical furniture. This can be substituted for traditional manual techniques of surveying and mapping. It can authenticate the appearance as well as examine the dimensional features of real objects employing accurate methods of surveying and mapping. [11] We have shown that surveying and mapping precise two-dimensional data and visual information can be obtained simultaneously. This will allow technical information to be collected to establish a database system of furniture with high quality and commercial application value. It can provide CAD systems, used for developing products by furniture enterprises, with underlying parameters and mapping materials without repeated construction. This will ensure

that products will conform to energy-saving, environmental-protection and may be employed to produce green and low-carbon manufacturing [12].

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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