

A Novel Modeling Method of “Jyoruri” Doll by Using Industrial CT Image Device and 3D Printer

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Abstract: In this paper, we propose a novel method that generates a precise replica model, which can be built by using an ordinary 3D printer. We utilize an industry CT (Computed Tomography) image device in order to measure the inside/outside of the doll, and model the doll shape and mechanism by using iso-surface and offset-surface generation techniques from CT images. Our approach has applied for reconstruction of “Jyoruri” doll, which is an old doll at the age of “Edo” period, and we have performed a revival concert of Japanese puppet show by using the replica dolls.

Keywords: Industrial CT image device, 3D printer, replica model, iso-surface, offset-surface, CAD

1 INTRODUCTION

During the Edo period, performances of “Joruri” dolls were being held, and it was very popular (Fig. 1). Recently, “Jyoruri” dolls and several old drawings were found at the house of “Suzue” family at Iwate prefecture (Fig. 2). The doll and the cloth had very damage, and it is difficult to use them in a revival concert of Japanese puppet show. Though we need to construct new dolls and cloth, craftsmen who made the doll are aging, and its production cost is very expensive. Therefore, we have started to construct the dolls by using 3D printer and state-of-the-art CAD (Computer Aided Design) technology.

In order to construct the precise replica dolls efficiently, we propose a novel method that utilizes an ordinary 3D printer.

We have used both industrial CT(Computed Tomography) system and 3D printer. We have developed iso-surface and offset-surface generation techniques by CT image, which was scanned by industrial CT system. First, we have scanned head, body, arm, folding fan, hat for two old dolls of “Sanbaso” and “Chitose” by using industry CT device. The scanned image are a set of 2D slice images, and we can utilize as 3D image when we scan in a narrow interval. In our case, we scanned each slice in a 1 mm interval. Our approach has applied for reconstruction of “Jyoruri” doll, which is an old doll at the age of “Edo” period, and we have performed a revival concert of Japanese puppet show by using the replica dolls.

When creating surface models of old dolls using conventional laser-based methods, measurements need to be carried out on both front and back surfaces, and the data then needs to be combined.

However, it is often difficult to match the boundaries, and there is a high possibility of missing certain features. It is also problematic to determine the thickness and internal configuration of the artifacts. To overcome these difficulties, in the present study, the entire shape of each object was captured as a 3D image using an industrial CT system, which provides information on thickness and internal configuration. CT systems come in two varieties, aimed at medical or industrial use, with the latter having the higher X-ray energy output. Though industrial CT systems are most commonly applied to plastics or thin metals, they can also be used on clay objects. Two industrial CT systems were used in the present study, a Micro CT (30~225 kV, Toshiba Corporation) and a METROTOM1500 (225 kV, Carl Zeiss Ltd.).

2 Our approach for making a doll

2.1 Overview

First, we scanned head, hat, we called “Eboshi” of “Jyoruri” doll, and invested the inside structure (See Figure 2). “Jyoruri” doll have a mechanism, such as open/close eyes, open/close mouth, and so on. The doll of “Sanbaso” has two eye situation and can be changed by puppet operator, in order to represent normal and anger state.

Next, we generate polygonal model of skin by using iso-surface technique. The generated polygonal model has large number of polygons because of high resolution of 3D image, we have reconstruct the polygonal model by using Poisson Surface Reconstruction (PSR) technique, which technique can approximate polygonal model into Poisson distribution function, and generate iso-

surfaces from the Poisson distribution function.

PSR techniques are effective for a large number of polygons that generated in high-resolution 3D images in comparison with edge or face based data reduction techniques. The left image of Figure 4 shows an original polygonal model that generated by iso-surface approximation, and the right image of Figure 4 shows re-meshing and smoothing polygonal model. We describe the detail of our modeling techniques in the next chapter.



Fig. 1 “Jyorui” dolls of “Edo” period



Fig. 2 “Jyorui” dolls (“Sanbasou” at “Suzue” Family)

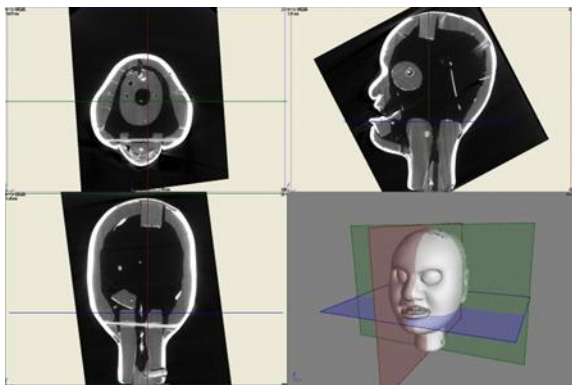


Fig. 3 Slice images of CT scan

3 A Modeling Method for Replica doll

3.1 Overview

Making replica model of old Japanese doll was divided into 6 processes as follows;

- 1) CT measurement of dolls
- 2) Measurement several accessory by lazer

scanner

- 3) Re-construction polygonal data
- 4) 3D modeling by 3D CAD system
- 5) 3D printing by 3D printer
- 6) Polishing and painting
- 7) Printing texture images to the fabric and sewing

The CT image measured by CT system was re-constructed into polygonal surface by using polyhedral approximation approach, such as iso-surface generation techniques [1-3].

An iso-surface is defined as a set of points that meet the following condition.

$$F(x, y, z) = C \quad (1)$$

Here, $F(x, y, z)$ is a three dimensional function and C is a constant value.

In order to generate a surface model and clean up model shapes, we used Volume Extractor ver. 3.0, which is a 3D image processing software developed by Iwate Prefectural University [4, 5]. The used iso-surface algorithm is “Marching Tetrahedral Algorithm”. Figure 4 shows a surface model created using Geomagic Freeform modeling system of 3D System Ltd. in order to re-mesh the polygonal surfaces.

By counting the number of pixels of CT image corresponding to the doll, its volume can easily be estimated. By weighing the doll, its density can then be determined without the need to touch it. For each doll, the thickness were determined to be the same as the weight of the old “Jyoruri” doll in order to perform the play in the same way.

The surface model was stored in STL (Standard Triangulated Language) file format, and printed by using 3D printer. We have used uPrint SE and Fortus 450mc of Stratasys Ltd.

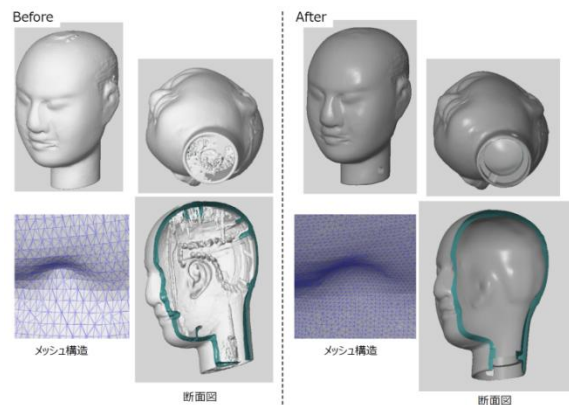


Fig. 4 A polygonal model of head created from CT image

3.2 Design of driving parts of the doll

“Sanbaso” has a mechanism of eye movement inside the head, and two kinds of eyes can be displayed by puppet operation. Figure 5 shows the head and the handle with the string. Puppet changes facial expressions with strings inside the head. Figure 6 shows two kinds of eyes of “Sanbaso”.

In order to design the mechanism, we have invested the inside by using CT system. Figure 7 shows the three-sided view inside the doll, and we found that it has several eye parts inside the head (Figure 8).

In order to realize it by 3D printer, we designed the similar mechanism. We have made a handle with a doll’s head with reference to the handle of the old doll of Figure 5. Figure 9 shows the parts modeled by 3D printer. We can manipulate the eye of the doll by pulling the string. Figure 11 shows the handle of the doll head, and it is the same for the head of each doll. The 3D printed models were painted with paint of acrylic material (Figure 12). The left image is “Sanbaso”, and the right image is “Chidori”.

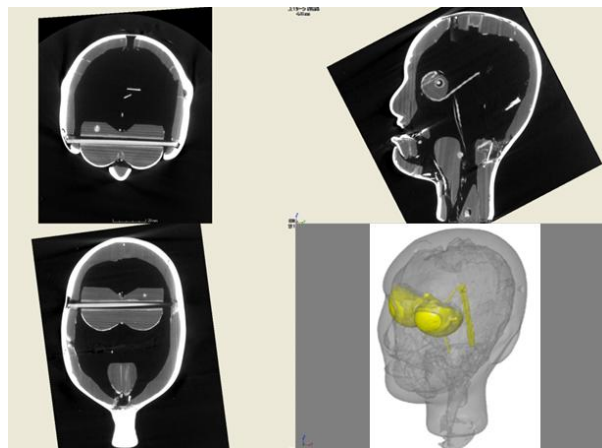


Fig. 7 Three-sided view of the head of “Sanbaso”

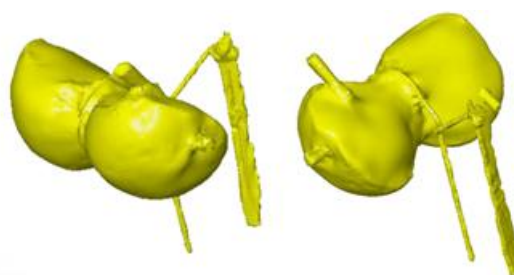


Fig. 8 The mechanism of two kind of eyes



Fig. 5 Head and handle of “Sanbaso”

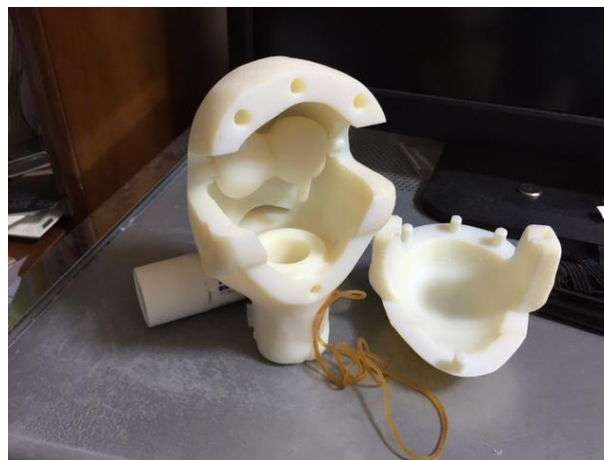


Fig. 9 The 3D printer model



Fig. 6 Two kind of eyes of “Sanbaso”

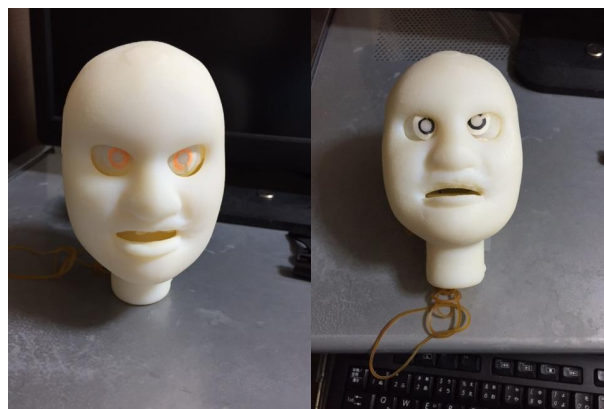


Fig. 10 Expression of two kinds of eyes

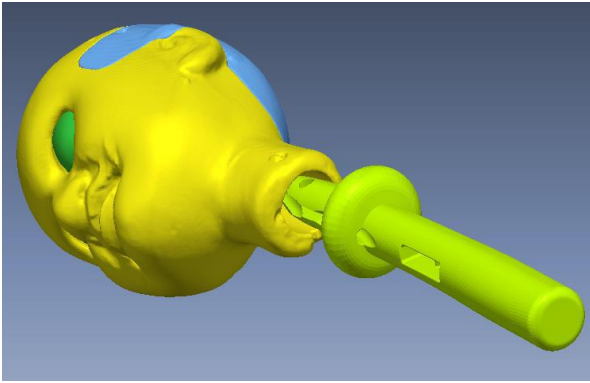


Fig. 11 The handle of the doll head



Fig. 15 Folding fan of “Sanbaso”(Before/after painting)



Fig. 12 A “Sanbaso” and “Chidori”



Fig. 16 3D shaped shoulder board (upper), harness (lower)

3.3 Reproduction of the accessory of the doll

At the same time, Eboshi (hat), shoulder plate, and folding fan were measured with 3D laser scanner, and they were modeled interactively by SolidWorks, which is 3D CAD System, and painted with paint of acrylic material (Figure 13-15). The shoulder board, harness inside “Kimono” were designed by using information from old documents and modeled by 3D printer (Figure 16).

The all parts were made by using uPrint SE (3D printer) of Stratasys Co., Ltd. Moreover, in order to make a doll look bigger, we have prepared the left and right arms inside the “Kimono”, which were created using wood.

3.4 Reproduction of “Kimono” of the doll

We took pictures of “Kimono”, and the photograph images were interactively edited in order to remove the fabric of the stains and dirt (Figure 17). We combined the texture images, and printed on the fabric by using a special printing machine which can print on fabric (Figure 18). The “Kimono” of “Jyoruri” were sewed by using the fabric (Figure 19). Figure 20 shows the final completed “Jyoruri” doll of “Sanbaso”.



Fig.13 Hat of “Sanbaso”(Before/after painting)



Fig.14 Hat of “Chidori”(Before/after painting)

4 CONCLUSION

We have proposed a novel method that produces a precise replica model, which can be built by using both industrial CT image system and an ordinary 3D printer. We utilize an industrial CT image device in order to measure the inside/outside of the doll, and the measured image information was used model the doll shape and mechanism.

We have also introduced our approach to approximate polygonal surface from the image information. The iso-surface computation and re-construction techniques are very important in our approach.

We have constructed two “Jyoruri” dolls, which are “Sanbaso” and “Chidori”. The replica models were used to performances by “Awaji-za” (Professional Puppet Theater Corp.) at the workshop. They are used model exhibition and panel exhibition at Morioka Machiya story museum.

Our approach can be applied for construction of very old, precious doll. Because the current situation is that the number of puppet maker or doll and doll maker is decreasing. Once 3D modeling is complete, it is very easy to produce these dolls.

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Fig. 17 Status of clothes of “Sanbaso”



Fig. 18 Texture capture and printed fabric



Fig. 19 Sewing of Kimonos



Fig. 20 Final completed jyoruri doll of “Sanbaso”

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