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Automatic identification of 3-D shape of head for wig manufacture

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Abstract: When making an order-made wig, in order to reduce cost, production of wig is performed in overseas factory where personnel expenses are usually cheap. In order to send the information of customer's head to the overseas factory, a wrap-model is often used. There are two problems in this method, one is that the production cycle time is too long, and another is that when the wig is damaged it is inconvenient for re-production. The aim of our research is to propose a wig manufacture system whose production cycle is short and re-production of the wrap-model is convenient. The key point is using three-dimensional (3-D) information instead of the customer's wrap-model. We use the 3-D image measurement method based on Optimal Intensity-Modulation Pattern (OIMP) projection technique to obtain each side of the wrap-model, and then synthesize it to represent the entire wrap-model. Then we send the 3-D information of the wrap-model to overseas factory by using the internet. In the overseas factory, according to the 3-D information of the wrap-model, we select one mold which is the fittest to produce the wig. Now, we are developing the application of the proposed method.

Keywords: Three-dimension measurement, Optimal Intensity-Modulation Pattern, wig manufacture, wrap-model, mold.

1 INTRODUCTION

For young ladies and famous actors who always need to change their fashion style in different places, the wear of wig is high, which will make them more confident and beautiful. When people get older, the hair will become less and less. In addition, the cancer patients who are undergoing the chemical treatment will cause a certain degree of hair loss. In these conditions, a wig is also necessary. The wig which is commercially available in a supermarket is cheap, but it is difficult to accord with the shape of the head accurately. The order-made can make a wig according to the shape of the user's head, but it is expensive and the production cycle is long.

When making a wig, besides the information of the size, we also need to know the property of the hair, the position of the whorl, the flow direction of the hair and the hair shades. In order to make the wig cost cheaper, almost all the production makers usually use the overseas factory instead of the factory in Japan. In order to send the information of customer's head to the overseas factory, a wrap-model is often used. In the overseas factory according to the sent wrap-model to select the fittest mold to make the wig, and send the completed wig back to Japan and reach the customer.

This method has two deficiencies. First of all, this production method will have to spend 30 days to finish the cycle, so the time needs to be shortened. It will take a long time for the consumers to decide whether to put on a wig for the first time. However, they hope to obtain the wig as soon as possible when decide the purchase once and ask it for production. So, shortening the time is necessary during the period of the production process. Secondly, when the wig is damaged the re-production of the wrap-model is inconvenient. As for the use of the wig, the customers do not want to be noticed by neighboring acquaintances or a friend. Therefore a lot of customers think that when the damage of the wig occurs they cannot go to the company or the school. Furthermore, the wig is used every day, so it should be re-purchased every 2 or 3 years. It is better to use the wrap-model which is the same as is produced several years ago. However, the material of the wrap-model is plastic film, and it's easy to become shrinkage and transformation by a secular variation. The re-production of the wrap-model is necessary and the customers have to come to the store again.

The target of our research is to solve the two problems. That is to shorten the time and to make the re-production more convenient. And in this way, the satisfaction of the customer could be improved.

The key point is using three-dimensional (3-D) information instead of the customer's wrap-model. There are many methods in 3-D measurement field. Such as the stereo vision method, it uses two cameras, just as the eyes of human. With the triangulation principle, the 3-D information was calculated. The system of stereo vision measurement method contains the camera and computer, and it has a wide range of measurement. However, when do the measurement, because it is difficult to obtain the character information, the reliability is very low. And it is also very hard to be automated. The Kinect developed by Microsoft could also get the color image and depth of the objects. The core of it is regardless of ambient lighting conditions, you can let Kinect COMS IR sensor of the sensible world. This sensor to sense the environment through the black and white spectrum: pure black on behalf of infinity, white represents infinity. Grey area between the black and white object that corresponds to the physical distance sensors. It collects every point within the vision, and form the environment around a picture that represents the depth of field images. Sensor to generate depth of field image flows at a rate of 30 frames per second, real-time 3-D rendering environment. However, the error of Kinect is larger than 1mm, it is cheap and well used in moving object. But what we are measuring is the Wrap-model, which record the human head's size and form, needs higher precision.

In this paper, we use the 3-D image measurement method based on Optimal Intensity-Modulation Pattern (OIMP) projection technique to obtain each side of the wrap-model, and then synthesize it to represent the entire wrap-model. Then we send the 3-D information of the wrap-model to overseas factory by using the internet. In the overseas factory, according to the 3-D information of the wrap-model, we select one mold which is the fittest to produce the wig.

2 CONFIGURATION OF MANUFACTURE SYSTEM

There are three parts of the configuration of the manufacture system. First we use the 3-D measurement to get the 3-D image of the wrap-model. Then take photos from multiple aspects to synthesis the images, so that we get the whole image of the wrap-model. Finally according to the 3-D image of the wrap-model, we will choose the fittest mold by using the software.

2.1 Improvement of the production process

Now, the production of the wig is like this, which can be clear seen in **Fig. 1**. First we record the size of the wig and other information of the hair by using the wrap-model which is made of plastic film (Step 1). Then we transport the wrap-model to the Indonesian manufacturing facility to make the wig (Step 2). According to the wrap-model, we select one mold which is the fittest (Step 3). After that we will make the wig by using the mold (Step 4). Finally we send the completed wig back to the customer in Japan (Step 5).

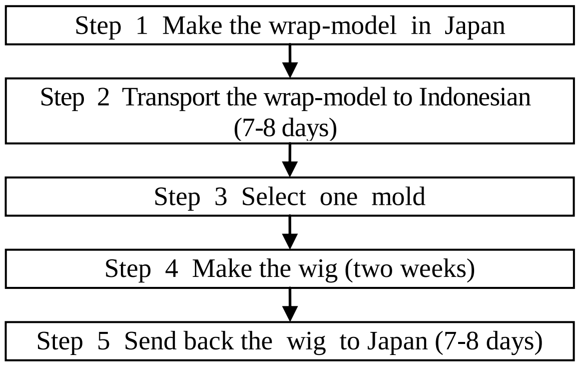

Fig. 1. The production flow of the wig

There are two problems in this method, one is that the production cycle time is too long, and another is that when the wig is damaged it is inconvenient for re-production. The aim of our research is to propose a wig manufacture system whose production cycle is short and re-production of the wrap-model is convenient. In order to achieve the goal of our study, we propose our method that is shown in **Fig. 2**. Instead of transport the wrap-model to overseas, we just take several minutes to measure the 3-D information of the wrap-model in Japan, and then take several seconds to send the 3-D information to Indonesian. Then we use the sent 3-D information to select the mold. In this way, the time of 7-8 days lost in transportation of the wrap-model can be saved. Therefore, the production cycle is shortened by 25%. In addition, we can make a database of the wig production information so that the re-production is convenient. This also

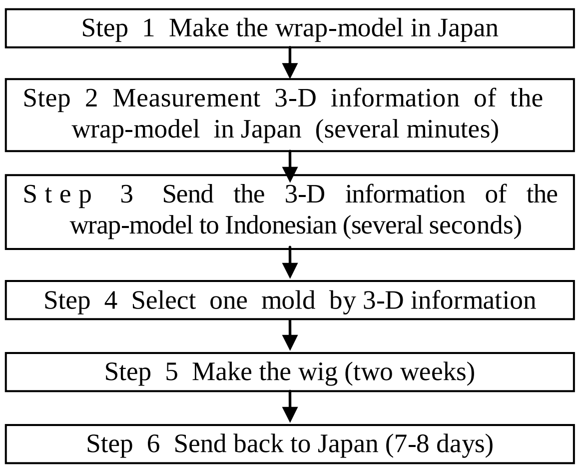

Fig. 2. The production flow of our method

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solves the second problem. As we can see from this method, how to measure the 3-D information of the wrap-model is become quite important.

In this study, by using the 3-D image measurement, we could find out the fittest mold to produce the wig for the elderly people and the cancer patients who are undergoing the chemical treatment and the necessity for wear of wig is high. We measure 3-D information of shapes of user's head in Japan and send the result to the overseas factory using the Internet. At the overseas factory, according to the 3-D information, we choose one mold which resembles the form of a user's head most, from the inside of tens of thousands of mold, to produce the suitable wig.

2.2 3-D measurement system

When we say 3-D measurement, it means that we measure the shape or the position of the target object. Now, in a lot of field the 3-D measurement is widely used, from topographic survey, building surveying to products, the human body and semiconductor industry and so on. 3-D is very practical. In addition, as the rapid development of information process and image process, in the research of machine vision, the 3-D measurement method which has high-speed, high precision and adaptability was needed.

In order to obtain the 3-D information of wrap-model, we use the 3-D image measurement technique based on pattern projection method. The composition graph of measurement system is shown in **Fig. 3**. We send the pattern by using the projector, according to the projection pattern, we can make a recognition of the stripes, and correspond the pattern between the original and the photo taken by the camera, after that we can get the 3-D image of the wrap-model [3].

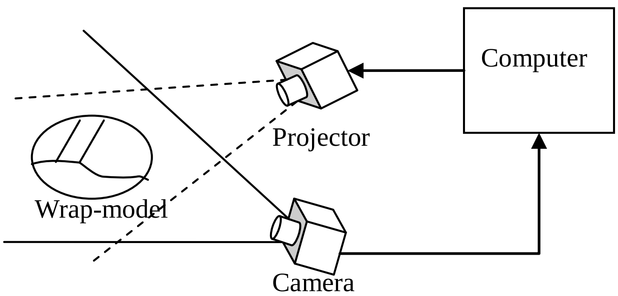


Fig. 3. Measurement system

The optimal intensity-modulation pattern projection method is a technique for improving the accuracy of the stripes address detection by optimizing the combination of stripes intensity of the projected pattern, and maximizing the intensity differences between adjacent stripes. The function is defined in cases like that when the projection light intensity difference of the stripes strength distribution combination $(I_1, I_2, \ldots I_N)$ is at the maximum, evaluation function $d(I_1, I_2, \ldots I_N)$ is also at the maximum.

$$d(I_1, I_2, ..., I_N) = \sum_{i=M+1}^{N} \sum_{j=1}^{M} k_j \left| I_i - I_{i-j} \right| \quad (1)$$

Here, *kj* is a weight factor. *M* is width of the filter on which evaluation function has been set. **Fig. 4.** shows the example of the projected pattern generated with formula 1[6].

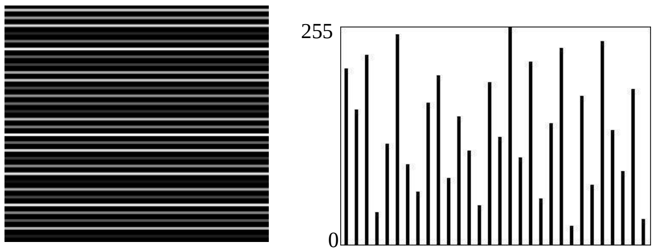
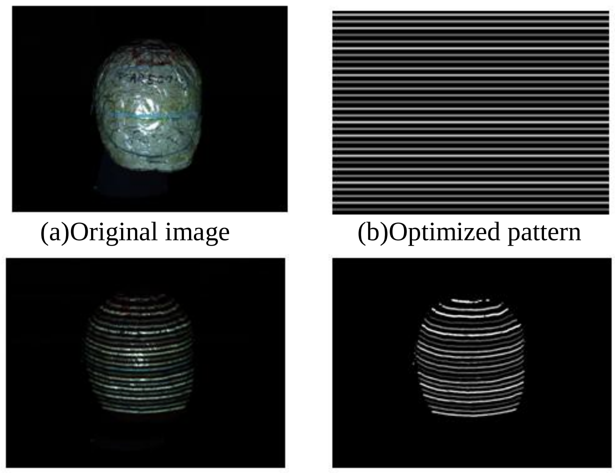


Fig. 4. Optimized pattern

As we can see from **Fig. 5, Fig. 5.(a)** shows the original image of the wrap-model taken by the camera. **Fig. 5. (b)** is the optimized pattern projected by the projector. And **Fig. 5. (c)** is the initial image of observation pattern image. After doing the image processing, we get the extracted pattern shown in **Fig. 5. (d)**. As we compare the stripes of the optimized pattern and the extracted pattern calculated by the software by using the triangulation principle, we could get the 3-D image of the wrap-model [2].



(a)Original image (b)Optimized pattern

(c)Observation pattern image (d)Extracted pattern

Fig. 5. Measurement principle

If we find out the corresponding relationship, we can use it to do the 3-D measurement with the triangulation principle, as is shown in **Fig. 6**.

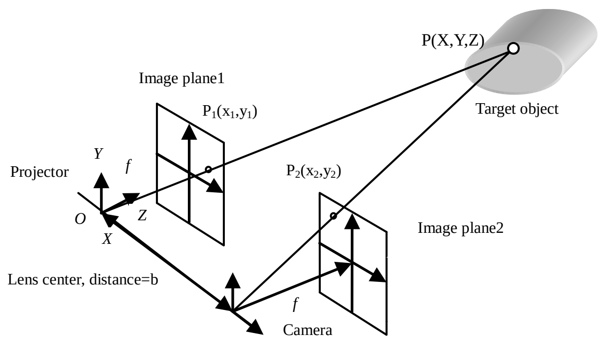


Fig. 6. Principle of calculation

$$\beta_1 = tan^{-1}(\boldsymbol{x}_1 / \boldsymbol{f}) \tag{2}$$

$$\beta_2 = tan^{-1}(\boldsymbol{x}_2 / \boldsymbol{f}) \tag{3}$$

While we find out viewing angle and observation plane coordinate, the coordinate of point P can be calculated out through triangulation principle.

$$\boldsymbol{X} = \frac{\boldsymbol{b}\boldsymbol{x}_1}{\boldsymbol{x}_1 + \boldsymbol{x}_2} \tag{4}$$

$$\boldsymbol{Y} = \frac{\boldsymbol{b}\boldsymbol{y}_1}{\boldsymbol{x}_1 + \boldsymbol{x}_2} \tag{5}$$

$$\boldsymbol{Z} = \frac{\boldsymbol{b}}{tan\,\beta_1 + tan\,\beta_2} \tag{6}$$

Because the relation of all stripes can be correctly detected by calculating the intensity value of noteworthy stripes in the observation image and adjacent stripes based on intensity change rule, this measurement method can be measured by only one projection and capturing two pictures. Therefore, it can be declared that it is a technique to achieve a high-speed measurement, and to expect the application of the measurement for the moving object possibly.

2.3 Synthesis of 3-D images

When performing 3-D measurement, since the measurement of the area can only fit into the camera in one measurement, it is not easy to get the entire circumference shape information of the object. So we need to synthesize the obtained measurement results from multiple directions. Therefore we can represent 3-D shape of the entire wrap-model.

Because 3D image of each aspect obtained is recorded in the independent coordinate system that depends on the camera respectively, it is necessary to convert coordinates into a common coordinate system. As can be seen from **Fig. 7.**The relation of coordinates *Xi* in an independent coordinate system and coordinates *X'i* in a common coordinate system is like the following formula [4].

$$X'_i = RX_i + t \tag{7}$$

Here, *R* is a rotation matrix, and *t* is a translation vector. The synthesis becomes possible by calculating *R* and *t*, and doing the geometric transformation. Feature points between two 3D images are necessary to calculate *R* and *t* by at least three points. Among *R* and *t*, *t* can be easily calculated by taking the differences of coordinates of the common feature points. In this research, we have calculated each coordinate of the center of gravity from the specified common feature points, and have matched them.

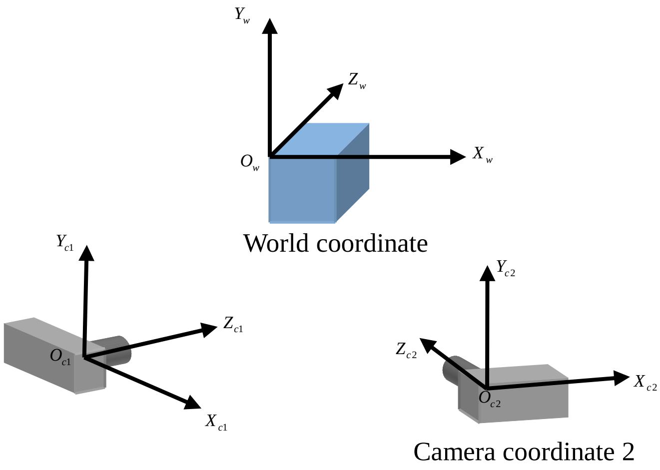


Fig. 7. World coordinate

Consideration of measurement error, *R* is calculated as follows:

$$\sum_{i=1}^{n} \left\| X'_i - RX_i \right\|^2 \rightarrow \min \tag{8}$$

According to formula 8, we can get the following which is the same meaning, as can be calculated:

$$\begin{aligned} & \sum_{i=1}^{n} \left(\left\| X'_i \right\|^2 - 2(X'_i, RX_i) + \left\| RX_i \right\|^2 \right) \\ &= \sum_{i=1}^{n} \left\| X'_i \right\|^2 - 2\sum_{i=1}^{n} (R^T X'_i, X_i) + \sum_{i=1}^{n} \left\| RX_i \right\|^2 \\ &= \sum_{i=1}^{n} \left\| X'_i \right\|^2 - 2Tr[R^T \sum_{i=1}^{n} X'_i X_i^T] + \sum_{i=1}^{n} \left\| X_i \right\|^2 \\ &= \sum_{i=1}^{n} \left\| X'_i \right\|^2 - 2Tr[R^T N] + \sum_{i=1}^{n} \left\| X_i \right\|^2 \end{aligned} \tag{9}$$

Here, *n* is the number of common feature points, when the correlation matrix is as follows:

$$N = \sum_{i=1}^{n} X'_i X_i^T \tag{10}$$

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The formula 8 is the same as solving the following formula:

$$Tr[R^T N] \rightarrow \max \tag{11}$$

We have solved this by using method of the quaternion [1].

The quaternion can represent rotation with four components, as a composite of a scalar and an ordinary vector, or as a complex number with three different imaginary parts.

$$q = (q_0, q_1, q_2, q_3) = q_0 + q_1 i + q_2 j + q_3 k \tag{12}$$

The rotation matrix is represented by the quaternion as follows:

$$R = \begin{bmatrix} q_0^2 + q_1^2 - q_2^2 - q_3^2 & 2(q_1q_2 - q_0q_3) & 2(q_1q_3 + q_0q_2) \\ 2(q_1q_2 + q_0q_3) & q_0^2 - q_1^2 + q_2^2 - q_3^2 & 2(q_2q_3 - q_0q_1) \\ 2(q_1q_3 - q_0q_2) & 2(q_2q_3 + q_0q_1) & q_0^2 - q_1^2 - q_2^2 + q_3^2 \end{bmatrix} \tag{13}$$

The rotation matrix *R* is obtained by the unit eigenvector to the maximum eigenvalue of four-dimensional matrix when $Tr[R^T N]$ is maximized [5].

$$\tilde{N} = \begin{bmatrix} N_{11} + N_{22} + N_{33} & N_{32} - N_{23} & N_{13} - N_{31} & N_{21} - N_{12} \\ N_{32} - N_{23} & N_{11} - N_{22} - N_{33} & N_{12} + N_{21} & N_{31} + N_{13} \\ N_{13} - N_{31} & N_{12} + N_{21} & -N_{11} + N_{22} - N_{33} & N_{23} + N_{32} \\ N_{21} - N_{12} & N_{31} + N_{13} & N_{23} + N_{32} & -N_{11} - N_{22} + N_{33} \end{bmatrix} \tag{14}$$

Thus, due to calculating rotation matrix, it is possible to synthesize 3D image.

2.3 Choice of mold

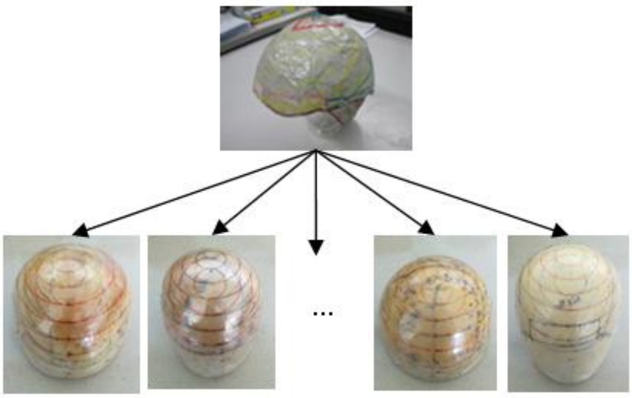

Fig. 8. Choose the mold

When producing the wig in overseas factory, we choose one mold which resembles the form of the user's head most, from the inside of tens of thousands of mold, to produce the suitable wig. As can be seen from **Fig. 8**.

First of all, we find out the highest point of the mold, then according to this point, draw 6 curves on the surface of the mold whose distance to the highest point are respectively 2cm, 4cm, 6cm, 8cm, 10cm, 12cm. In the same way, by using the 3-D image information on computer, we find out the 6 curves on the surface of the wrap-model. By comparing the length of the curves, we find out which mold have the smallest error from the wrap-model. We will use this mold as the fittest to produce the wig.

3 EXPERIMENTS

In this study, the purpose of the experiment is to find out the fittest mold by using the measured 3-D information of the wrap-model. First of all, we use the 3-D shape measurement system to obtain the image of the wrap-model, then synthesis the images to get the entire shape information. According to the 3-D information of the wrap-model we could select the fittest mold to make the wig.

3.1 synthesis of the wrap-model

In this experiment, we measured from the direction of the front, rear, right and left and right above to obtain the three-dimensional information of the entire wrap-model.

It can be seen from the results shown in **Fig. 9** that the wrap-model could be synthesized correctly and 3-D information of the entire wrap-model could be obtained.

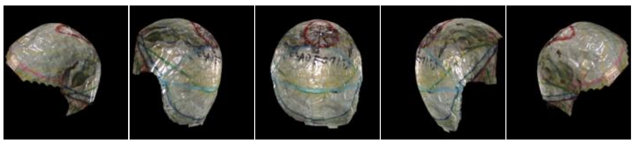

Fig. 9. Synthesis wrap-model

3.2 Choose the mold

Now we get the 3-D image of the wrap-model, then we will use the software to calculate the data of the image to find out the fittest mold. The method is that we find out the highest point of the wrap-model, and according to this point, draw 6 curves on the surface of the wrap-model whose distance to the highest point are respectively 2cm, 4cm, 6cm, 8cm, 10cm, 12cm. After that we compare the form and size between the 3-D image of the wrap-model and the mold, to find out the fittest mold. We will use this mold as the fittest to produce the wig. As can be seen from **Fig. 10**, **Fig. 10(a)** is the flat figure and **Fig. 10(b)** shows the space curve length, the sixth curve is broken so it can't be used.

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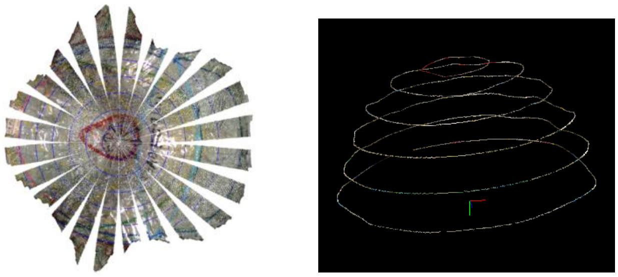

(a) Flat figure (b) Space curve length

Fig. 10. Curves on the surface of the wrap-model

After that we compare the data between the wrap-model detected by the software and the mold detected by hand, to find out the fittest 3 mold from 100 mold models. The result can be seen from **Table 1**.

Table 1. Wrap-model and the fittest three molds

Lap	Wrap-model (mm)	The first fittest(mm)	The second fittest(mm)	The third fittest(mm)
1	118.9	123	123	122
2	240.7	239	241	239
3	339.5	338	339	340
4	417.4	418	420	419
5	473.5	473	472	471
6	/	502	509	501
error	/	0.53%	0.56%	0.59%

As we can see from the result, the error is very small, but actually we could not always find out the fittest mold, sometimes the mold and the wrap-model don't fit quite well. As we can see from **Fig. 11**, this mold fit quite good except the back side of the mold.

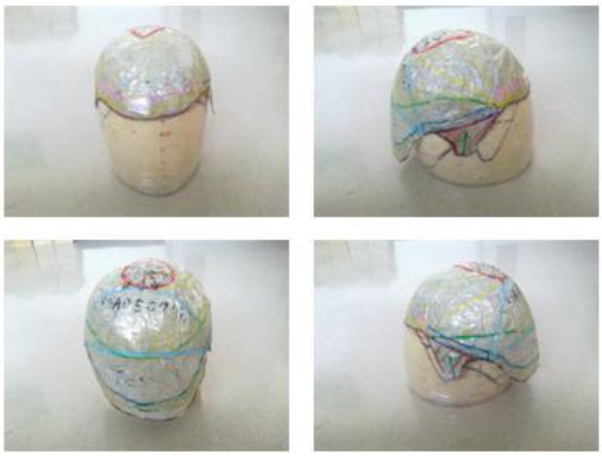

Fig. 11. The result

4 CONCLUSION

In this study, we propose a new manufacture system whose production cycle is short and re-production of the wrap-model is convenient. The key point is using 3-D information data instead of the customer's wrap-model. In order to obtain the 3-D information of wrap-model, we use the 3-D image measurement method based on Optimal Intensity-Modulation Pattern (OIMP) projection technique. When performing 3-D measurement, since the measurement of the area can only fit into the camera in one measurement, it is not easy to get the entire circumference shape information of the object. So we need to synthesize the obtained measurement results from multiple directions. Therefore we can represent 3-D shape of the entire wrap-model. Then we send the 3-D information data of the wrap-model to overseas factory by using the internet. In the overseas factory, according to the 3-D information of the wrap-model, we select one mold which is the fittest to make the final wig.

But there are also problems that the mold and the wrap-model don't fit quite well actually. Maybe we should change the curves we select in the further study.

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