Basic Study on Design Tool of Hula Costumes

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Abstract

Miyazaki Prefecture has a large hula population, probably due to its similarity to Hawaii in mythology and climate. On the other hand, many hula costumes are handmade, and it costs tens of thousands of yen to produce an original design. So we are developing a 3D CAD (computer-aided design) system for hula costumes, based on the idea that we can reduce the number of failures by checking the behavior of the fabric when danced in the designed costume before production.

Keywords: Cloth-Simulation, Hula Costume, Computer Graphics, Costume Design

1. Introduction

In recent years, three-dimensional computer graphics (3DCG) technology has been applied in various fields; there are several apparel design tools using 3DCG, but there is no precedent specific to the hula.[1, 2] Therefore, as a preliminary step in developing a design tool for hula costumes, we developed a tool that allows users to select and simulate the design and color of a skirt. In addition to the design and color, this tool has the ability to deform the human body model based on the body measurements. We are also planning to develop a function to change the length of the skirt. With these features, you will be able to find the right skirt size for you.

2. Research Background

In this study, we improved the 2D hula costume design tool shown in Fig. 2, which outputs the execution results as shown in Fig. 1, to output the execution results in real time with 3D animation as shown in Fig. 3. By changing from 2D to 3D animation, it is easier to visualize the finished skirt.

Fig. 1. 2D design tool execution results.

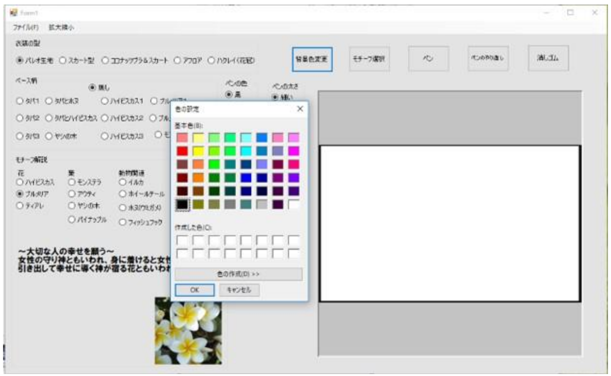

Fig. 2. 2D design tool.

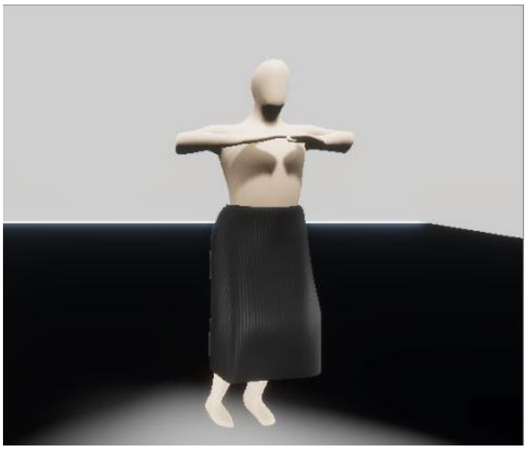

Fig. 3. 3D design tool execution results.

3. Simulation Environment

This study was simulated in the environment shown in Table 1.

Table 1. Simulation Environment

OS	Windows 10 Pro
Memory	16GB
Processor	Intel® Core ™ i7-7700 3.60GHz
GPU	Quadro M4000
Programming language	C#
Development Software	Unity
CG modeling software	Blender

4. Processing details of each function

This section describes the processing of the functions we have developed for deforming the human body model based on body measurements and selecting the color and design of the skirt.

4.1. *Transformation of human body models based on body measurements*

The human body model will be deformed based on the measurements of the actual body. In this case, we will measure the length of the four parts of the body and the circumference of the seven parts. Then, by inputting the measurements into the input form shown in Fig. 4, the human body model is deformed into the same body shape as the person who took the measurements.

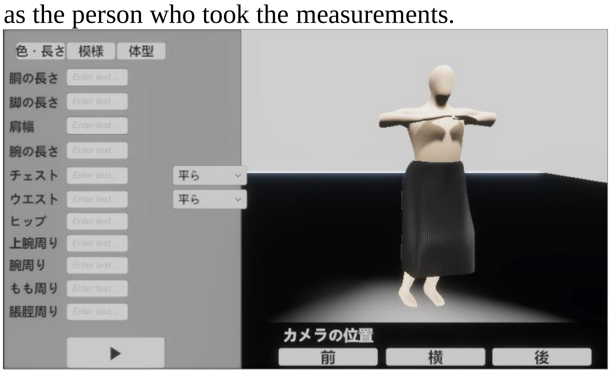

Fig. 4. Input form for measurement values.

4.1.1. Transformation of the length of each part

This time, assuming the height of the human model before deformation to be 160 cm, the following procedure was used to determine the magnification/reduction ratio of the length of the torso, legs, shoulder width, and arms.

(i) The vertical length of each bone of the human body model was calculated using the coordinates of the image in Fig. 5. The results are shown in Table 2 below. The head, neck, chest, back, hips, buttocks, thighs, shins, and feet were measured for vertical length. Shoulders, upper arms, forearms, and hands were measured in horizontal length.

Table 2. Length of each bone in coordinates.

Part	Length
Head	79
Neck	40
Chest	66
Back	54
Waist	43
Hip	49
Thigh	146
Shin	150
Foot	37
Shoulder	69
Upper Arm	74
Forearm	98
Hand	59

(ii) The vertical lengths of the head, neck, chest, back, hips, thighs, shins, and feet were added together and all divided by the head length of 79. The result of that calculation is about 8.40.

(iii) Since we assumed that the model before deformation is 160 cm, we divide the result of step 2 by 160. The result of this calculation is about 19.04.

(iv) Then, the following formula is used to calculate the length of each bone on the process of 160cm height, L_{Born}.

$$L_{Born} = 19.04 \times L_i \div 79 \tag{1}$$

Let L_i be the length of each bone in the coordinate.

(v) Finally, dividing the actual measurements of each part of the body by the calculation results of step 4 determines the magnification/reduction ratio of the parts of the human body model.

The measured body, leg, and arm lengths are the sum of the back/waist, thigh/shin, and upper arm/forearm lengths, respectively.

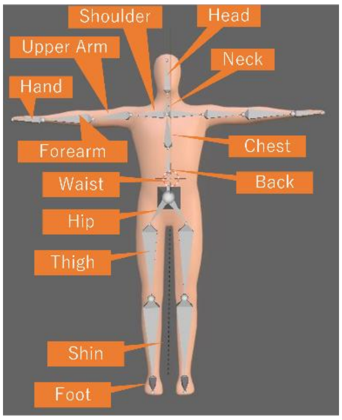

Fig. 5. 3D model of a human body (front view).

4.1.2. Transformation of the length of the perimeter of each part

Assuming the height of the human model before deformation to be 160 cm, the following procedure was used to calculate the magnification/reduction ratio for the chest, waist, buttocks, upper arms, forearms, thighs, and shins.

(i) The long and short diameters of the chest, waist, hips, upper arms, forearms, thighs, and shins of the human model were calculated using the coordinates of the images in Figures 5, 6, and 7. The results are shown in Table 3 below.

Table 3. Long and short diameters of each part.

Part	Long Diameter	Short Diameter
Chest	148	96
Waist	112	67
Hip	125	76
Upper Arm	37	33
Forearm	29	26
Thigh	67	57
Shin	47	41

(ii) Consider the cross section of each part of the body as an ellipse. The approximate formula for the length L of the perimeter of the ellipse is shown below.[3]

$$L = 2\sqrt{4(a-b)^2 + \pi^2 ab} \tag{2}$$

Here, a is the short diameter and b is the long diameter.

(iii) If the ratio A of short and long diameters is fixed, the following equation can be used to calculate the short and long diameters from the perimeter length. When $b = Aa$,

$$a = \sqrt{\frac{L^2}{4\{4-(8+\pi^2)A + 4A^2\}}} \tag{3}$$

(iv) From the short and long diameters a and b in Step 3, the magnification factors s_a for the short diameter and s_b for the long diameter are calculated by the following formula.

$$s_a = \frac{2a}{19.036 \times L1_i \div 79} \tag{4}$$

$$s_b = \frac{2Aa}{19.036 \times L2_i \div 79} \tag{5}$$

Here, $L1_i$ is the long diameter of each part, and $L2_i$ is the short diameter of each part.

Since the ratio of the long and short diameters of the chest and waist can vary greatly from person to person, in this study, for the chest and waist, there were three items to choose from: "flat," "slightly round," and "round" in terms of the shape seen from the side. The ratios of the long and short diameters when each item was selected are shown in Table 4 below.

Table 4. Ratio of the long and short diameters of each part when

each item is selected.

Item	Ratio (Long Diameter: Short Diameter)
Flat (Chest)	154.2 : 100
Slightly round (Chest)	150 : 100
Round (Chest)	145 : 100
Flat (Waist)	100 : 59.8
Slightly round (Waist)	100 : 70
Round (Waist)	100 : 80

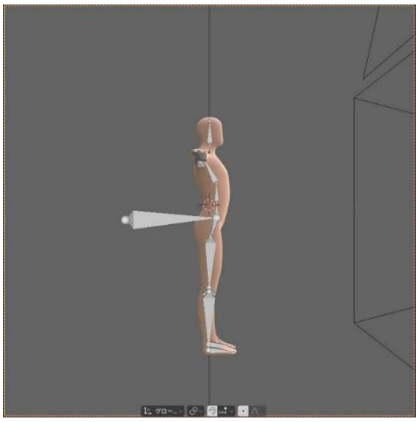

Fig. 6: 3D model of a human body (side view).

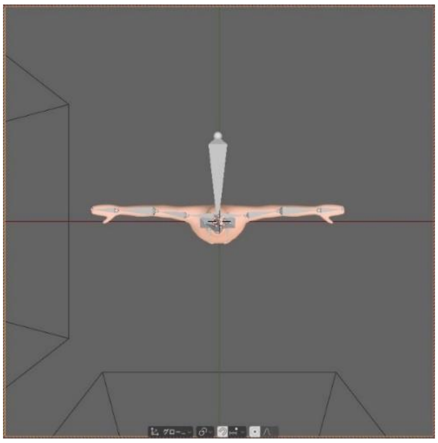

Fig. 7: 3D model of a human body (top view).

4.2. *Change the color of the skirt*

The color of the skirt is changed by moving each RGB slider in Fig. 8.

Fig. 8. Change the color of the skirt.

The RGBA color model was used to represent the colors. In this model, colors are represented by determining the R (red), G (green), B (blue), and A (transparency) parameters from 0% to 100%.[4] In this system, the parameter is set to 0 for 0%, and 1 for 100%. A is fixed at 1 to avoid transparency. The initial state is (R,G,B,A)=(0,0,0,1), and the color can be changed by moving each slider. The slider is 0 on the left and 1 on the right. The processing procedure is shown below.

(i) Set the color parameters to (R,G,B,A) = (0,0,0,1) and the color of the skirt to black.
(ii) If the skirt has a texture set, set the texture parameter to null.
(iii) Get the RGB parameters of the current skirt color.
(iv) Get the value of each slider.
(v) Assign the value of each slider to each RGB parameter.

By repeating steps 3 through 5, the color of the skirt can be changed in real time.

4.3. *Change the pattern of the skirt*

The pattern of the skirt can be changed by clicking on the button for each pattern in Fig. 9.

Fig. 9. Change the pattern of the skirt.

The pattern is changed by setting the skirt color to the white parameter (R,G,B,A)=(1,1,1,1) and mapping the chosen texture to the skirt when the button is pressed.

Currently, we are using Unity's "Triplanar", which projects images onto the skirt, so the pattern stays in a certain position when the human model moves.

5. Execution result

The following shows the results of the run when the human model was deformed and the color and pattern of the skirt were changed.

5.1. *Results of deforming a human body model*

Fig. 10 shows a variant of the human body model based on the average of measurements of Japanese males aged 20 to 24. This time, the torso length and arm length were calculated approximately, and the average values of the entire Japanese male population were input for hip and upper arm circumference.[5, 6, 7]
The result, as you can see in Fig. 10, is that the legs have rotated inward. This is thought to be due to the enlarged hip bones.

Fig. 10. Model of an average Japanese male body shape.

The following Fig. 11 to 13 show the deformation of the human body model when the shape of the waist from the side is changed to "flat", "slightly round", and "round" on the model of the average of the measurements of Japanese men aged 20 to 24. It can be seen that there is a difference in the roundness of the shape of the stomach between the "flat" and "rounded" waists.

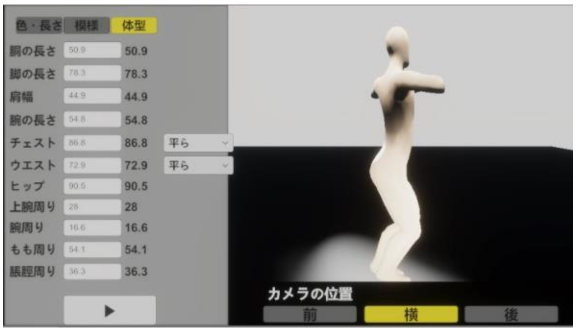

Fig. 11. Change the shape of the belly (flat).

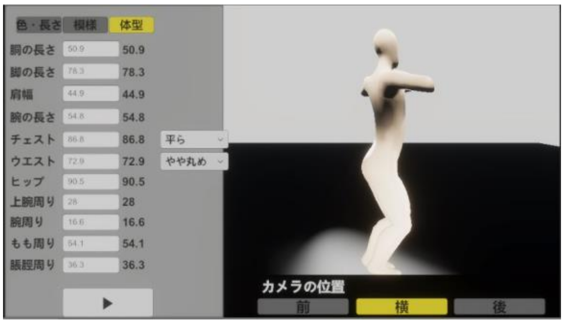

Fig. 12. Change the shape of the belly (slightly round).

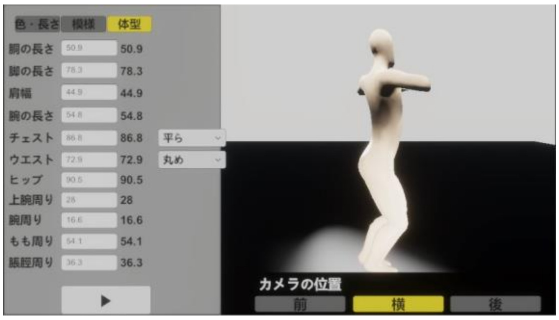

Fig. 13. Change the shape of the belly (round).

Fig. 14 shows a variant of the human body model based on the average of measurements of Japanese women aged 20 to 24. This time, the torso length and arm length were calculated approximately, and the average of all Japanese women was input for the upper arm circumference.[5, 8, 9]
The result, as can be seen in Fig. 14, is an unnatural balance between the head and the torso, since the head size remains the same as before the deformation.

Fig. 14. Model of an average Japanese female body shape.

The following Fig. 15 to 17 show the deformation of the human body model when the shape of the chest from the side is changed to "flat", "slightly rounded" or "rounded" on the model of the average of the measurements of Japanese women aged 20 to 24. It can be seen that there is a difference in roundness in the shape of the chest between "flat" and "rounded" chests.

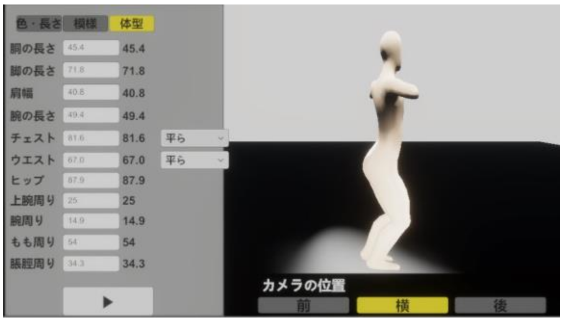

Fig. 15. Change the shape of the chest (flat).

Fig. 16. Change the shape of the chest (slightly round).

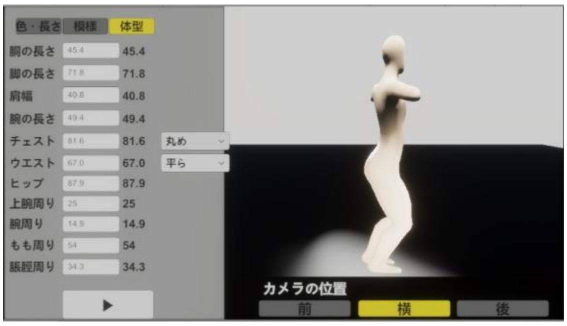

Fig. 17. Change the shape of the chest (round).

5.2. *Result of changing the color of the skirt*

When all the color sliders are moved to the right, the skirt color will be white, as shown in Fig. 18. When only the green slider is moved to the right, the color of the skirt will be green, as shown in Fig. 19.

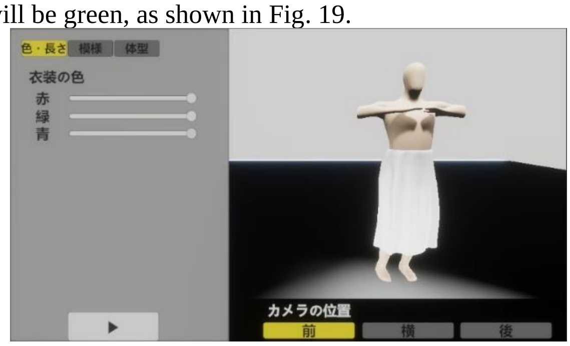

Fig. 18. Change the color of the skirt (white).

Fig. 19. Change the color of the skirt (green).

5.3. *Result of skirt pattern change*

The results of the run when the skirt pattern is set to Hibiscus are shown in Fig. 20 and Fig. 21. When the human body model is not moving as shown in Fig. 20, the texture mapping to the skirt appears to be successful. However, when the animation of the human body model is played back as shown in Fig. 21, the texture is projected at a fixed position, indicating that it does not follow the movement of the skirt.

Fig. 20. Change the pattern of the skirt (before playing the animation).

Fig. 21. Change the pattern of the skirt (during animation playback).

6. Consideration

The following is a discussion of the results of the transformation of the human body model, the change of the color of the skirt, and the change of the skirt pattern.
In the first function, the deformation of the human body model, the expansion of the hips caused the legs to rotate inward. This could be solved by rotating the hip bones in accordance with the hip expansion. In addition, when the model was transformed into a model of an average Japanese female body shape, the balance of the body shape became unnatural due to the fact that the head size did not change. This could be solved by changing the size of the head to match the expansion of the torso length, etc.
In the future, we will input the average human body dimensions of a four-year-old, which is the age when most people start hula dancing, and verify how the human body model deforms.
In the second function, changing the color of the skirt, the color looks a little bright, probably due to the lighting in the virtual space. In the future, we would like to adjust the lighting so that it expresses more correct colors.
In the third function, changing the pattern of the skirt, we found that the texture was projected at a fixed position and did not follow the movement of the skirt. This suggests that the method of mapping the image onto the skirt needs to be reviewed.

7. Conclusion

This time, we have developed a tool that can deform the human body model based on measurements and change the color and pattern of the skirt. As for the deformation of the human body model, we would like to do four things in the future: rotate the hip bones to match the expansion of the hip, change the size of the head to match the body shape, deform the human body model based on the average human body size of four-year-olds who tend to start hula dancing, and display an explanation of where to measure the length.
For the color change, we would like to adjust the lighting to represent the correct color. We would also like to display the percentage of the slider that has been moved when it is moved.
In changing the pattern, I would like to revise the texture mapping method so that the image can be mapped while following the skirt correctly.
And in the future, I would like to add the ability to change the length of the skirt, display the length, and generate a pattern, to develop a practical tool.

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