Shoes Recommendation System Based on Clustering of 3D Shoes Data

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***Abstract*—There are some problems in internet shopping such as products return due to size mismatch. This problem is serious in internet shopping of shoes because wearing feeling are particularly important for shoes. So, we aim to make a shoes recommendation system using three-dimensional data of foot and shoe in order to decrease problem of size mismatch. This paper proposes a visualization method for fitting condition of foot and shoe and feature extraction method of shoe three-dimensional data. We also create a linear regression model that predicts the features of the reference shoes. Standard size table of shoe is made by applying the regression model of reference shoes to other shoes.**

Keywords—Three-dimensional data; Linear regression Clustering; Foot; Shoes

I. Introduction

In recent years, internet shopping is widely used due to the spread of the Internet. There are some problems that consumers often order shoes that can't be worn. Because each shoes has different width even if these shoes made by other manufacturer have same length. Moreover even shoes of the same manufacturer may have different width if the model is different.

To solve this problem, we try to make a shoes recommendation system using three-dimensional data of foot and shoe. To make a recommendation system, a large amount of three-dimensional data for extracting features is required. So, we developed a three-dimensional measurement instrument of foot that everyone can use easily [1]. In the future we will collect data sets of foot and shoe. Then, clustering is performed using extracted features, and recommendation system is made by predicting the shape adaptation class between foot class and shoe class. However, three-dimensional data of foot has not been collected now. Only shoe data of three kinds of manufacturers are already collected.[1]

In this study, we try to extract features from shoe data, and make standard size table of shoe by linear regression using features of shoe. First, a linear regression model that predicts features of shoe width and shoe length from other features is created using reference shoes. Next, shoe width and shoe length of the other shoes is predicted by inputting features of the other shoes to the created linear regression model. By expressing multiple kind of shoe in the feature space of the reference width and length, shoes having features similar to the consumer's shoes are recommended for consumer. In addition, we try virtual fitting of foot and shoe data in recommendation system. We align the three-dimensional data of foot and shoe, and calculate the distance between foot and shoe data. The fitting condition is visualized by coloring the data that depending on the distance between the two data. In this study, feet data getting by three-dimensional measuring instrument and shoe inner data getting by Flickfit proprietary technology are used (Fig.1 and 2).

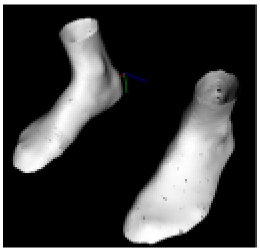
Fig.1 3D foot data

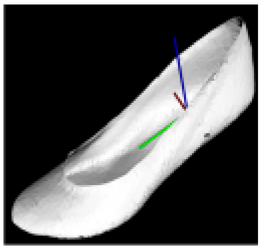
Fig.2 3D shoe data

II. Proposed Method

A. Feature extraction

Features of shoe data are necessary to create a standard size table of shoe by a linear regression model of reference shoes. The three-dimensional data of the shoe in Fig.2 is mesh data. We obtain the distance by detecting the mesh in the search direction using Tomas Möller method [2].

First, we extract the data of sole and perform Principal Component Analysis (PCA) to get principal component from three-dimensional data of shoe. The direction of the first principal component is defined as the length direction of the shoe, and the direction of the second principal component is defined as the width direction. Next, we get the longest width at 30% or more in front of the shoe length which is the feature corresponding to the width of shoe. This feature is defined as the reference width. Also, we obtain a line connecting the intersection of the heel and the reference width in length direction from the heel. The length of this line is defined as the reference length. A conceptual diagram of the reference width and length is shown in Fig. 3.

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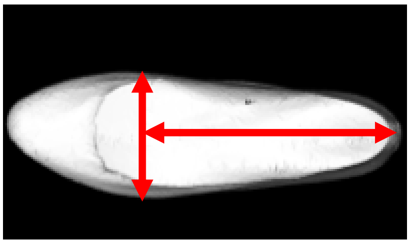

Fig.3 Reference width and Reference length

In addition to the reference width and length, we also obtain 105 different features based on the measuring points determined by Foot, Foot wear and Health Association [3] as shown in Fig. 4 and 5. For example,

- The distance from both ends of reference width to heel (green lines)
- The width at the 30% point of shoe length from heel (blue line)

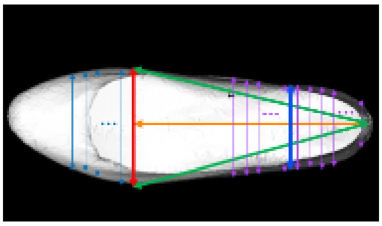

Fig.4 Shoe features (Top view)

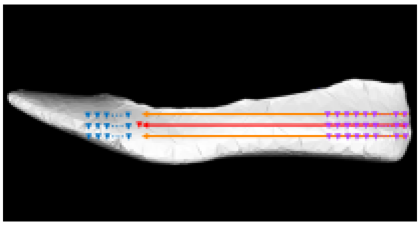

Fig.5 Shoe features (Side view)

B. Selection of reliable features

Features of shoe are extracted by the same method independent on kind of shoe, but shoe shape is various. If the shape of the shoe is different, there is a possibility that extracted features is obtained from different position. Therefore we obtain only reliable features which are extracted from same position.

If kind of each shoe is different, width of each shoe is different even if these shoes have same length. Also, there are various shapes of the feet too. However, it is considered that the foot length has a linear relationship with features such as width. Therefore, we assume that features of the same position have linear relationship with shoe length in the same kind of shoes. We count data whose the distance between each data and the regression line of shoe length and certain feature is higher than the threshold. At this time, if total count number is less than a certain value, it is assumed that the feature is reliable. As a result, 21 reliable features were selected from 105 features. One of the linear regression of reliable features and unreliable features are shown in Fig. 6 and 7. RANSAC (Random Sample consensus) algorithm is used for linear regression of shoe length and features. In this case, the RANSAC algorithm creates a temporary model with random selected data from the data set, and adds it to the model candidate if there are few outliers. Finally, the algorithm creates a model that doesn't consider outliers by choosing the regression model that most closely matches all the data from the model candidates.

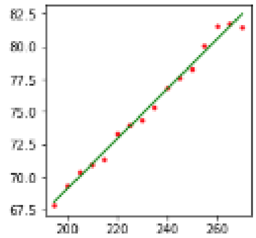

Fig.6 Reliable feature

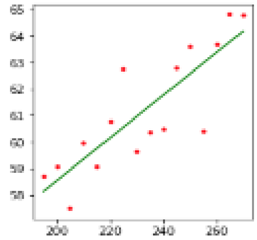

Fig.7 Unreliable feature

C. Linear interpolation of features

We assume that features of the same position have linear relationship with shoe length in the same kind of shoes, and select reliable features. However, the actual features are not perfectly linear with shoe length due to noises occurring when of getting inner data of shoe. These noises are thought to have a bad influence when creating a standard size table of shoe. Therefore, we perform a linear regression of the shoe length and feature that selected for each shoe, and let the feature value of each data be the predicted value of the regression line. The same interpolation is performed for the reference width and length.

D. Prediction of shoe length and width by linear regression

At first, we decide reference shoes in order to create a standard size table of shoe. Next, two linear regression models for predicting the reference width and length of the reference shoe are created by using the selected 21 features. The reference width and length of the other shoes are predicted from the features of the other shoes by using the two linear regression models based on reference shoe. By predicting with a linear regression model, it is possible to express multiple kinds of shoe in the standard size table of two-dimensional feature space that is made by the reference width and length based on the reference shoe. The prediction results of two manufacture shoes using the linear regression model are shown on table1. The score shows the coefficient of determination.

Each shoe has a length and width independently determined by the manufacturer for each kind, and any manufacturer has nine kinds of width standards, i.e. A, B, C, D, E, EE, 3E, 4E and F. Japan Leather Shoes Industry Cooperative Association [4] has kind of shoes called 288 pumps. The 288 pumps has shoe with length of every 5 mm from 195 mm to 270 mm. And shoe of each length have nine widths. So, we treat 288 pumps as reference shoes.

TABLE I. RESULT OF PREDICTION

	Prediction target	*Number of data*	*score*
Reference Shoes(training)	Reference Length	216	0.9998
	Reference Width	216	0.9846
Reference Shoes(test)	Reference Length	72	0.9998
	Reference Width	72	0.9779
Manufacturer1	Reference Length	153	0.9982
	Reference Width	153	0.6567
Manufacturer2	Reference Length	302	0.9982
	Reference Width	302	0.4402

E. Alignment of foot and shoe three-dimensional data

The foot always touches the shoe at the bottom. Therefore, we align the three-dimensional data of foot and shoe based on foot sole and shoe sole. At first, bottom of foot and bottom of shoe data are projected on a two-dimensional plane. The projected two-dimensional data is filled uniformly by the closing process. Next, two-dimensional data of foot sole and shoe sole are analyzed by the PCA. The first principal component, the second principal component, and the center of gravity of the two-dimensional data of foot and shoe are aligned by rotation and translation. The three-dimensional data of foot and shoe are moved in the same as the two-dimensional data, and the position of the foot heel is aligned to the position of shoe heel.

The alignment results are shown in Fig. 8. In these figures, two foot data with different size are used so that the result is easy to understand.

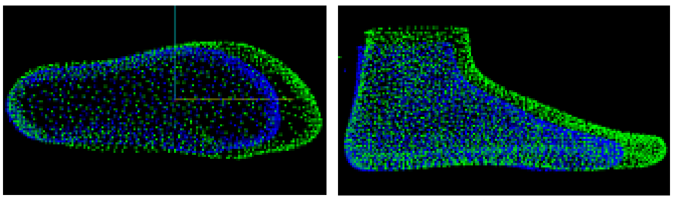

Fig.8 Alignment result

F. Distance detection between three-dimensional data

To get the distance between foot and shoe data, we detect the surface of the shoe corresponding to each point of foot data. At first, to make a combination of the three points from the target point and neighboring points, neighbor points of each foot data are searched. Next, a normal vector is obtained from triangle that is consisted of three points. Finally, multiple normal vectors are obtained, and the face of the shoe existing in the direction of the average of the normal vectors is detected.

III. EXPERIMENT

A. Creating standard size of shoe

The reference width and length of the reference shoes, the manufacturer1 and the manufacturer2 are shown in Fig. 9. The reference width and length after the linear interpolation are shown in Fig. 10. The result of linear regression of reference width and length based on reference shoes are shown in Fig. 11. Also, all of linear regression results are shown in Fig. 12.

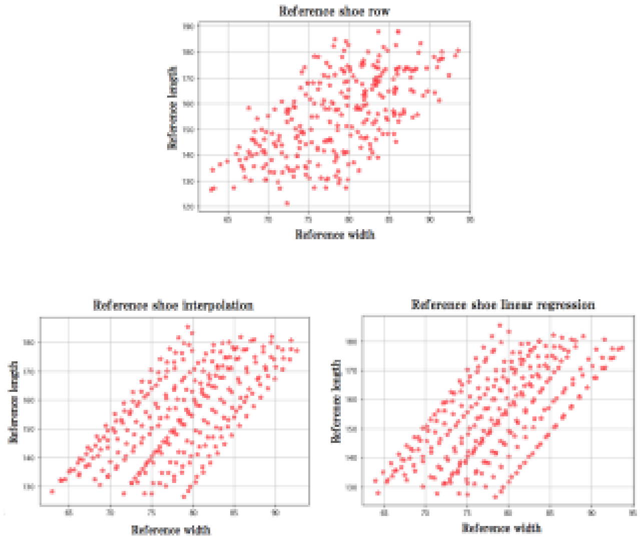

Fig.9 Transition of standard shoe data

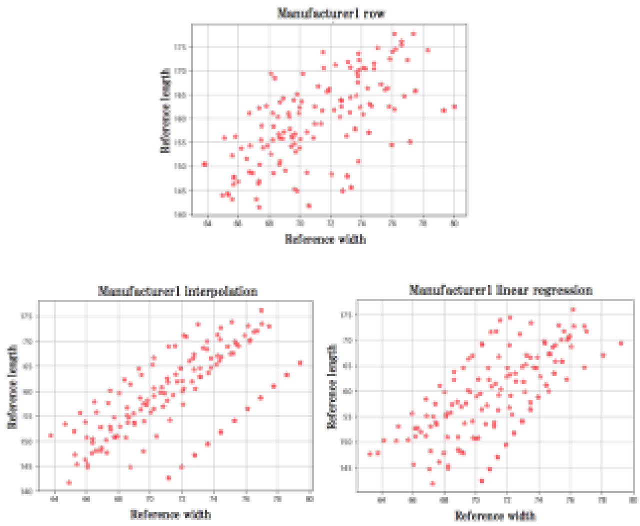

Fig.10 Transition of manufacturer1 shoe data

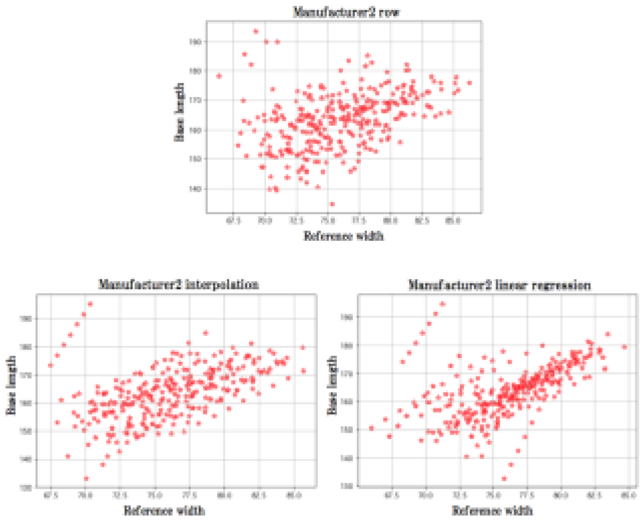

Fig.11 Transition of manufacturer2 shoe data

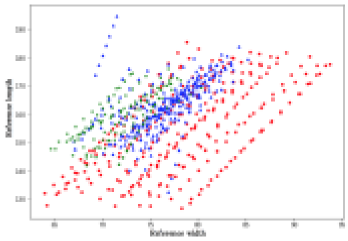

Fig.12 Result of linear regression of all data

B. Alignment of foot and shoe and visualization of distance between both data

As shown in Fig. 13, fitting condition is expressed by coloring according to the distance between the foot and shoe data. Result of virtual fitting with 220, 235 and 250 mm shoe data and 230mm foot are shown in Fig. 14, 15 and 16.

Fig.13 Relationship between color and distance

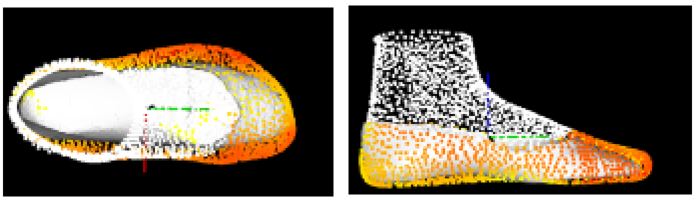

Fig.14 Virtual fitting results(Shoe size is 220 mm)

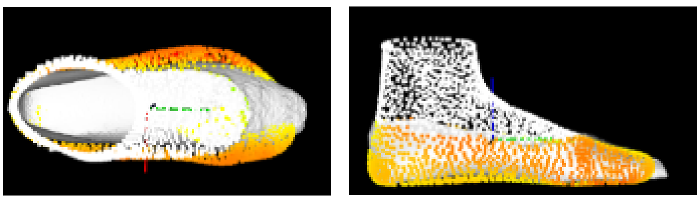

Fig.15 Virtual fitting results(Shoe size is 235 mm)

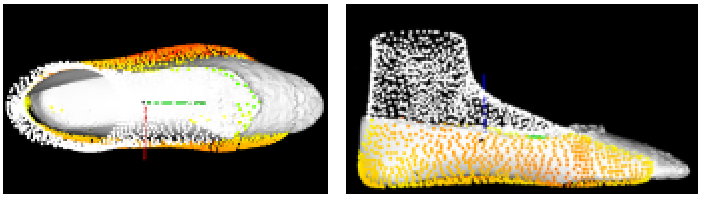

Fig.16 Virtual fitting results(Shoe size is 250 mm)

IV. DISCUSSION

A. Creating standard size of shoes

As shown in Table 1, the prediction scores of reference width of manufacturer1 and manufacturer2 are both low. The reason why the scores become low is that it is predicted by the linear regression model of the reference shoes. We think that the score difference between the reference shoes and other shoes is the industrial standards difference between manufacturers.

It is considered that same kind of shoes are plotted at equal intervals for each type in different feature space. However, as shown in Fig. 10, the data intervals for each type after prediction is not constant as compared with the data after linear interpolation. It is considered that the prediction result is not correct because of the accuracy of features obtained from three-dimensional data.

B. Alignment of foot and shoe and visualization of distance between both data

As shown in Fig. 14, 15 and 16, it can be confirmed that the points near the heel and the sole are yellow. Therefore, it can be seen that the position is aligned around the heel and the sole. However, the width of the foot is larger than the width of the shoe in the figure. It is considered that the width of foot become larger than width of shoe because the pressure is not considered when wearing shoes.

V. CONCLUSION

This paper proposed a method of visualization of fitting condition and feature extraction from three-dimensional data to construct shoes recommendation system. Also, a standard size table of shoe was created by a linear regression model using features of shoe data. In the feature, we will collect foot and shoe data, and try clustering in both data using features. Then we will make shoes recommendation system based on classes of foot and shoe data using machine learning.

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[2] Tomas Möller:"Practical Analysos of Optimized Ray-Triangle Intersection" ,http://fileadmin.cs.lth.se/cs/Personal/Tomas_Akenine-Moller/raytri/

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Home Page : http://fha.gr.jp/

[4] Japan Leather Shoes Industry Cooperative Association
Home Page : http://www.zkkr.jp/