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Motion Feature Quantification
of Different Roles in *Nihon-Buyo* Dance

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1. Introduction

As the development of smart biped robots has been thriving, research and development of personal robots with unique personalities will become an important issue in the next decade. For instance, we might want to have robots capable of affording us pleasure by chatting, singing or joking with us in our homes. Most of these functions are realized by verbal communications. However, motion of a whole body, namely non-verbal communication, also plays an important role.

We can get information concerning the personality of a subject when we observe his or her body motion. We may receive various impressions through their body motions. This means that human body movements convey emotion and the personality of the individual. Personality might be the involuntary and continuous expression of emotions, which are peculiar to an individual.

The aim of our research is to investigate the mechanism of expressing personality through body motions, the mechanism of how we get emotional impressions from body motions, and finally to investigate what kind of motion we should give robots in order to make them express specific personality and/or emotional impressions.

For this purpose, we employ Kansei information processing techniques, motion capturing, feature extraction from motion data and some statistical analyses, including regression analysis. The word "Kansei" is a Japanese word which is used to express some terms like "feeling" and "sensibility" in English. Kansei information processing is a method of extracting some features which are related to Kansei conveyed by the media we receive or, in contrast, a method of adding or generating some Kansei features to media produced by computers.

In Kansei-related research, some types of psychological experiments are indispensable in order to measure the Kansei factor which humans receive. With this methodology we can measure quantitatively, for instance, the effect of a color, or combination of colors, on an observer.

We employ motion-capturing techniques for obtaining human body movements, which has become common among the communities of film and CG animation production. Several systems are commercially available nowadays.

For this investigation, we used the motions of *Nihon-buyo*, which is a Japanese traditional dance. The reasons why we chose this type of traditional dance form are as follows: First

and most importantly, we are conducting research on digitally archiving traditional Japanese dancing, and we are well accustomed with this kind of dance [1, 2]. Secondly, dance in general provides us with much more artistic body motions compared to the human body motions found in our everyday lives, and it should be rather easy to find and discriminate emotional factors in dance movements. In contrast, it is hard to distinctively find and discriminate subtle emotional factors in ordinary body motions.

2. Related works

Some of the related research investigating the relationship between body motion and emotion will be reviewed below.

We have already conducted research in which we used intentionally generated typical body motions with seven different emotions called the "7 motives." The relationship between the physical characteristics of body motion and the impressions has been studied [3].

Nakata et al. investigated the relationship between body motion and emotional impressions by using a simple, pet-like toy robot capable of swinging its hands and head [4]. The motions were generated with a control program, and the change of joint angles could be measured. They used angular velocities and accelerations as motion features. A factor analysis was used for finding the relationship between these features and the Kansei evaluation obtained by human observers. In this research, a theory called LMA, Laban Motion Analysis, was used for characterizing motions. However, since the motions they dealt with were very simple, this model could not be directly applied to human body motions during dance.

LMA theory was also applied to the analysis of body motion [5]. In this case, human body motions during dance, specifically ballet, have been analyzed, and labels indicating LMA features have been attached to motions in each frame. The motion was obtained using a motion-capture system, and some LMA elements have been obtained by analyzing the change of spatial volume which a person produces during dance. The results obtained with this program have been compared with the results obtained by a LMA specialist.

The theory of LMA was also applied in [6], in which modification of neutral motions of CG character animation was done using the concept of LMA Effort and Shape factors in order to add some emotional features to the motion.

Although LMA is a powerful framework for evaluating human body motions qualitatively [5], we think it is not universally applicable, but that some kinds of experimental psychological evaluations are required for its reinforcement.

Motions of Japanese folk dance [7] were analyzed, and fundamental body motion segments and style factors expressing personal characteristics were extracted. Then new realistic motions were generated by adding style factors to the neutral fundamental motions displayed with CG animation. A psychological evaluation was not conducted in this research.

Neutral fundamental motions, such as those motions used when one picks up a glass and takes a drink of water, were modified by applying some transformations to the speed (timing) and amplitude (range) of motion for generating motions with emotions in CG [8]. However, the body motions used were simple.

A psychological investigation was performed to determine what the principal factors were for determining the emotions attached to motions [9]. In this research, by using LEDs attached to several body parts, e.g. head, shoulder, elbows, ankles and hands, motions were

analyzed. The result was that the velocity of these body parts had a strong relationship with the emotions expressed by the motions. The results are convincing, but more elaborate analysis of body motions might be required.

A method for extracting Kansei information from a video silhouette image of the body was developed [10]. In this case, the analysis method based on LMA was also implemented. However, the motion of each individual body part was not considered in this research.

3. *Nihon- Buyo* and the work *Hokushu*

The origin of *Nihon-buyo* can be traced back to the early *Edo* period, i.e. early 17t century. Its style matured during the peaceful *Edo* period, which lasted for almost 300 years. Literally interpreted, *Nihon-buyo* means "Japanese dance," but there are many dance forms in Japan other than *Nihon-buyo*. Different from folk dances, *Nihon-buyo* is a sophisticated and stylized dance performance, and its choreography has been maintained by the professional school systems peculiar to the Japanese culture. This differentiates *Nihon-buyo* from other popular folk dances in Japan, which are voluntarily maintained by the general population. The choreography of many *Nihon-buyo* is strongly related to the narratives, which are sung by choruses. Their subjects are taken from legendary tales or popular affairs.

We used a special work of *Nihon-buyo* named *Hokushu* in which a single player performs multiple roles or characters with different personalities successively. The work, often hailed as one of the most elaborately developed dances, depicts the changing seasons and seasonal events as well as the many peoples who come and go in the licensed "red-light district" during the *Edo* era. Despite the name, used here due to the lack of an appropriate English term, the area was a highly sophisticaed, high-class venue for social interaction and entertainment, where *daimyo*, or feudal lords, would often entertain themselves. It is synonymous with "*Yoshiwara.*" *Edo* was a typical class society, and people depicted in the play belong to several different social classes and occupations.

In our experiment described below, a female dancer played both female and male characters, although it is sometimes performed by a male dancer. It is said that the *Hokushu* performance requires professional skills and that it is difficult for most people, let alone novices, to portray the many roles in dance form. The play we used for our analysis was performed by a talented, professional dancer.

The *Hokushu* is performed with no particular costume or special hand props, except for just a single folding fan. Photos in Table 1 show a dancer wearing traditional Japanese attire, which is still worn today on formal occasions.

4. Motion capture and the method of analysis

We have used an optical motion capture system (Motion Analysis Corporation, EvaRT with Eagle and Hawk cameras) to measure the body motions of this dance. Figure 1 shows a scene of motion captured in our studio. Reflective markers are attached to the joints of the dancer's body, and several high-precision and high-speed video cameras are used to track the motion.

In our case, 32 markers were put on the dancer's body, and the movement was measured with 10 cameras (see Figure 2). The acquired data can be observed as a time series of three-dimensional coordinate values (x, y, z) of each marker in each frame (frame rate is 60 fps).

Role		Duration	Explanation	Photos
Name	Gender			
Yukyaku	Male	2 sec.	Visitor at a licensed red-light district	
Tayu	Female	35 sec.	"*Geisha*" in the highest rank	
Hokan	Male	9 sec.	Professional entertainer, Comedian	
Bushi	Male	5 sec.	Bureaucrat, "*Samurai*"	
Mago	Male	5 sec.	Horse driver, Coachman	
Shonin	Male	5 sec.	Merchant, Businessman	
Yujo	Female	5 sec.	"*Geisha*"	
Enja	Female	6 sec.	Neutral character, Dancer	

Table 1. Multiple roles performed by a dancer


Fig. 1. Motion capture
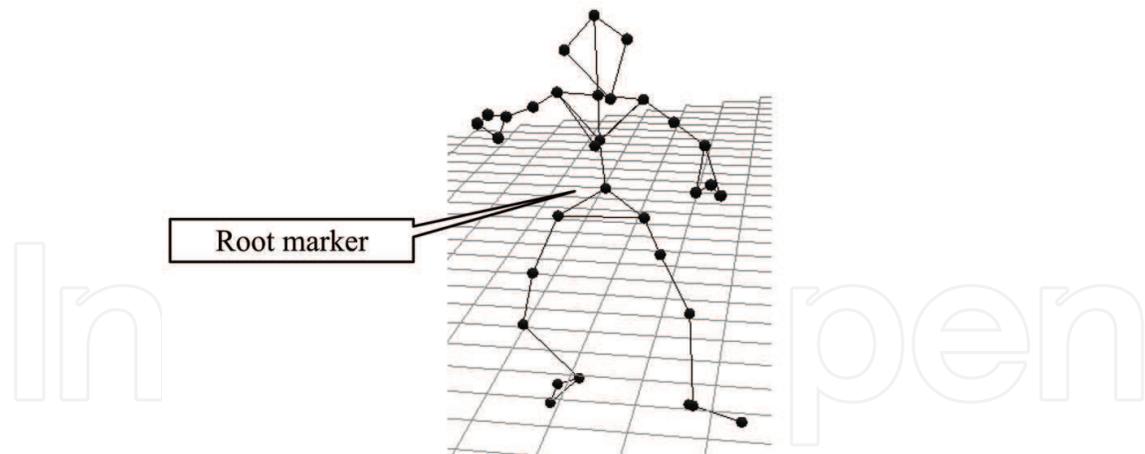
Fig. 2. Positions of markers

5. Psychological rating experiments

In order to examine what type of impression is perceived from the body movement of the eight characters in *Hokushu*, we first conducted a psychological rating experiment using the stick figure animation (see Figure 3) of the motion capture data. Thirty-four observers (21 men and 13 women) participated in this experiment. The mean and the standard deviation of age among the 34 observers are 21.7 and 2.73 respectively. They had no experience in dance performances of any kind and no particular knowledge about this particular dance and the Japanese traditional culture. The animation was projected on a 50-inch display with no sound. Stick-like figure animation and muted audio were used to allow the audience to focus on the Kansei expressed through the body movements alone, discarding other factors, e.g. facial expression, costume, music, etc.
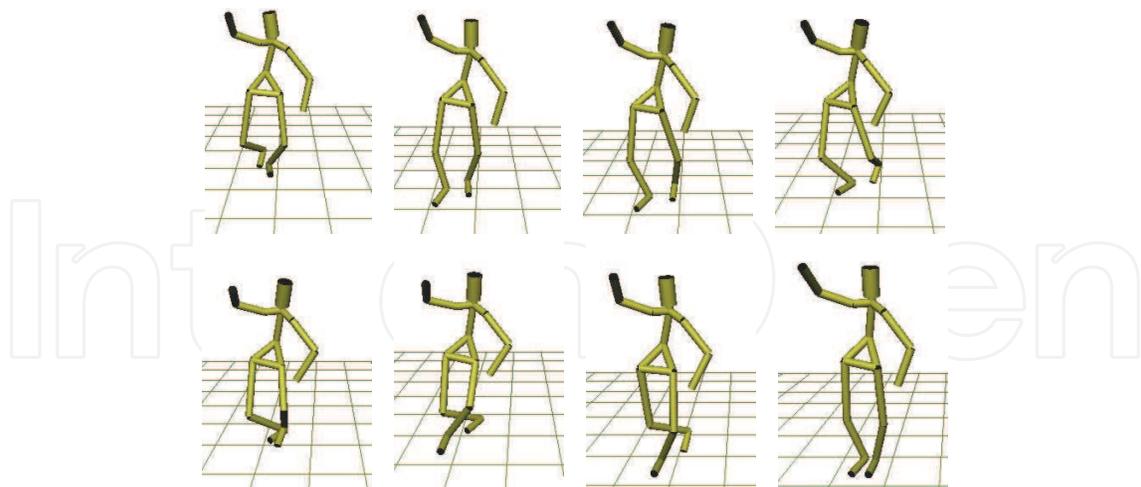
Fig. 3. Stick figure animation used in the experiment

After each movement was shown, the observers were asked to answer the questions on the response sheets. In this rating, we employed the Semantic Differential questionnaire. In the Semantic Differential questionnaire, 18 image-word pairs, which are shown in Table 2, were used for rating the movements. We selected these 18 word pairs, which we considered suitable for the evaluation of human body motions, from the list presented by Osgood [11].

The observers rated the impression of the movement by placing checks in each word pair scale on a sheet.

The rating was done on a scale ranking from 1 to 7. Rank 1 is assigned to the left-hand word of each word pair and 7 for the right-hand word as shown in Table 2. Using this rating, we obtained a numerical value representing an impression for each of the body motions from each subject. Table 3 shows the results of the experiment, in which mean values of the rating scores were obtained from all of the subjects for each image-word pair obtained from the eight motions listed.

```
                    1   2   3   4   5   6   7
      Light      --+--+--+--+--+--+--+--   Dark
      Strong     --+--+--+--+--+--+--+--   Weak
      Complex    --+--+--+--+--+--+--+--   Simple
      Sharp      --+--+--+--+--+--+--+--   Blunt
      Hard       --+--+--+--+--+--+--+--   Soft
      Excitable  --+--+--+--+--+--+--+--   Calm
      Straight   --+--+--+--+--+--+--+--   Curved
      Graceful   --+--+--+--+--+--+--+--   Awkward
      Serious    --+--+--+--+--+--+--+--   Humorous
      Stable     --+--+--+--+--+--+--+--   Changeable
      Beautiful  --+--+--+--+--+--+--+--   Ugly
      Pleasurable -+--+--+--+--+--+--+--   Painful
      Large      --+--+--+--+--+--+--+--   Small
      Colorful   --+--+--+--+--+--+--+--   Colorless
      Noble      --+--+--+--+--+--+--+--   Vulgar
      Cheerful   --+--+--+--+--+--+--+--   Gloomy
      Masculine  --+--+--+--+--+--+--+--   Feminine
      Angular    --+--+--+--+--+--+--+--   Rounded
```

Table 2. 18 image-word pairs

Image-word pairs	Yukyaku	Tayu	Hokan	Bushi	Mago	Shonin	Yujo	Enja
Light-Dark	2.62	5.21	4.15	4.79	3.47	1.91	2.97	4.74
Strong-Weak	3.26	3.62	4.76	4.38	4.74	3.29	4.26	3.35
Complex-Simple	5.29	3.09	4.03	5.41	3.97	3.94	4.00	5.09
Sharp-Blunt	3.62	4.62	4.62	5.15	4.76	3.76	3.94	3.26
Hard-Soft	4.65	3.26	4.85	4.12	5.06	5.53	5.24	2.97
Excitable-Calm	3.94	5.82	5.29	5.88	4.21	2.97	3.82	5.26
Straight-Curved	3.29	4.24	4.65	3.88	5.59	5.06	5.06	2.21
Graceful-Awkward	3.41	2.74	3.18	3.06	4.97	4.74	3.12	2.76
Serious-Humorous	3.82	2.68	3.62	3.18	5.29	6.00	3.79	2.21
Stable-Changeable	3.06	3.29	3.47	2.79	5.24	4.44	3.71	2.26
Beautiful-Ugly	3.09	3.12	3.47	3.59	4.50	4.12	2.88	3.09
Pleasurable-Painful	3.29	5.00	3.85	4.44	3.32	2.06	3.32	4.32
Large-Small	3.18	3.91	4.79	4.65	4.68	2.76	3.65	4.09
Colorful-Colorless	3.47	4.68	4.38	5.42	4.38	3.03	2.91	4.74
Noble-Vulgar	3.44	2.76	3.56	3.59	4.94	4.76	3.38	2.91
Cheerful-Gloomy	3.03	4.97	3.82	4.85	3.62	1.76	3.38	4.65
Masculine-Feminine	3.62	3.94	5.00	3.56	3.38	2.44	5.76	3.38
Angular-Rounded	4.06	3.97	5.00	4.21	5.12	5.06	5.29	2.79

Table 3. Mean values of scores in 18 image-word pairs

Then we applied a principal component analysis, PCA, (based on a correlation matrix) to the mean value of the rating value shown in Table 3 and obtained the principal component matrix. Four significant principal components were extracted, which are PC1-PC4 shown in Table 4.

Table 4 shows the values of factor loading of each word pair to four principal components, and the shaded areas in the table indicate the significant image-word pair ratings to each principal component, whose magnitude is larger than 0.6. In the shaded area in the PC1 column, we can find the word pairs "excitable-calm," "pleasurable-painful" and "cheerful-gloomy," etc., which are often used to represent activity. Hence, it is interpreted that PC1 is a variable related to the "activity" behind the motion. Similarly, PC2 is related to "potency," because we can find the word pairs "sharp-blunt," "strong-weak" and "large-small" in that column. For each PC3 and PC4, only a single word pair, "masculine-feminine" and "complex-simple" respectively, is found. Therefore, we could interpret PC3 as a variable related to "gender" and PC4 as being related to "complexity."

	PC1	PC2	PC3	PC4
Light-Dark	-0.884	0.413	0.105	-0.174
Strong-Weak	0.076	0.897	-0.240	0.332
Complex-Simple	-0.272	-0.341	0.370	0.805
Sharp-Blunt	-0.083	0.912	0.049	0.002
Hard-Soft	0.908	0.125	-0.259	0.277
Excitable-Calm	-0.886	0.426	0.091	-0.045
Straight-Curved	0.733	0.580	-0.275	-0.193
Graceful-Awkward	0.886	0.179	0.398	-0.042
Serious-Humorous	0.978	0.099	0.171	-0.018
Stable-Changeable	0.849	0.421	0.042	-0.232
Beautiful-Ugly	0.637	0.478	0.596	-0.038
Pleasurable-Painful	-0.930	0.301	-0.022	-0.168
Large-Small	-0.435	0.815	0.076	0.264
Colorful-Colorless	-0.714	0.508	0.474	0.050
Noble-Vulgar	0.872	0.283	0.378	0.105
Cheerful-Gloomy	-0.905	0.379	0.051	-0.071
Masculine-Feminine	-0.206	0.240	-0.916	0.200
Angular-Rounded	0.774	0.447	-0.417	0.062
Eigenvalue	9.669	4.397	2.294	1.122
Variance (%)	53.715	78.140	90.885	97.120

Table 4. Results of PCA for the rating experiment

Consequently, we can conclude that we recognize the characteristics of motions of *Hokushu* based on these four aspects: activity, potency, gender and complexity.

Figure 4 is a plot of the principal component score of each motion datum. Observing Figure 4, we can see that, for instance, a motion of *Shonin* is active, strong and masculine, a motion of *Tayu* inactive and complex and a motion of *Yujo* feminine.

By this analysis, the impressional features of each motion were clarified. However, the impressional features obtained so far by the experiment were based on the subjective perception of the observers. We then had to examine the relationship between the subjective feature perceived by the observers and the physical characteristics of body movements.

(a) PC1 vs PC2   (b) PC3 vs PC4
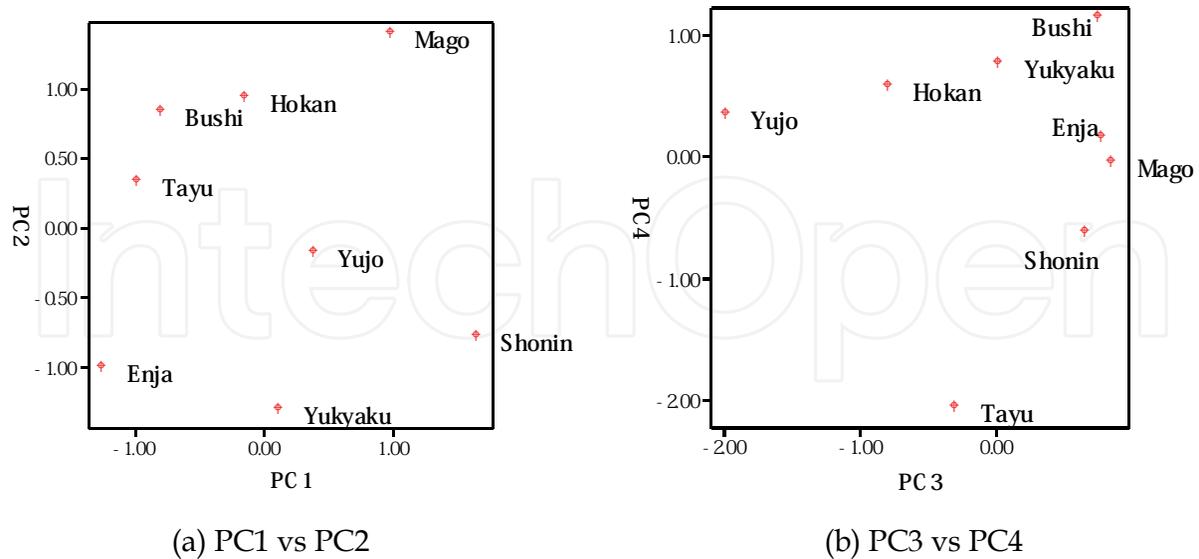
Fig. 4. Plot of PCA score for each motion

6. Feature values for body motion

In this research, we extracted 22 physical parameters from the motion capture data. These parameters consist of four types. One is related to the velocities of certain body parts, namely, the velocities of the head, the left and right hands, the waist and the left and right feet.

The second parameter is related to the shape of the body: angle of the left and right knees. The third category is related to the size of the body: the area span of the body, which is the size of the space occupied by the body, and the height of the waist. The last parameter is related to smoothness: acceleration of waist motion.

As stated earlier in Section II, it was found that the velocity of body parts, especially end effectors, had a strong relationship with the emotions expressed by motions [9]. Looking at this result, we mainly focused on the velocity (actual magnitudes of velocities) of end effectors. In addition to these velocity features, we also used several features related to the shape of the body, size of the body and size of the space occupied by the body. In order to evaluate the smoothness of the whole body motion, we used the acceleration of the motion of the waist.

Velocities of end effectors are calculated by using relative coordinates measured from the origin placed at the root marker shown in Figure 2. Contrastingly, the velocity and acceleration of the waist is calculated in the absolute coordinate system.

Mean values and standard deviation (SD) values of these physical parameters were used for the feature values representing human body motions. We simply disregarded the variation in time of these values during the motion by taking an average and an SD. However, we also found that these kinds of simple feature values gave fairly satisfactory results in the recognition of dance body motion, which was used for our dance collaboration system [12].

We also applied a principal component analysis (based on a correlation matrix) for these physical parameters to obtain a principal component matrix. Four principal components were extracted, which are shown as PC1 through PC4 in Table 5.

By observing Table 5, it can be understood that PC1 correlates to "speed," PC2 the "height of the waist (angle of the knees)," PC3 the "area of the body" and PC4 the "variation of

height of the waist." Figure 5 is a plot showing the principal component scores of our motion data.

	PC1	PC2	PC3	PC4
Mean velocity of the head	0.808	-0.344	0.036	0.427
Mean velocity of the left hand	0.928	0.325	-0.037	-0.094
Mean velocity of the right hand	0.850	0.467	-0.094	-0.208
Mean velocity of the waist	0.783	-0.511	0.138	0.295
Mean velocity of the left foot	0.541	-0.649	0.337	0.231
Mean velocity of the right foot	0.905	0.066	-0.118	-0.072
SD velocity of the head	0.431	-0.460	0.599	-0.046
SD velocity of the left hand	0.747	0.496	0.101	-0.397
SD velocity of the right hand	0.778	0.525	0.038	-0.311
SD velocity of the waist	0.586	-0.572	0.461	-0.053
SD velocity of the left foot	0.657	-0.686	0.035	0.159
SD velocity of the right foot	0.902	-0.275	-0.212	-0.011
Mean angle of the left knee	0.164	0.748	0.592	0.235
Mean angle of the right knee	0.113	0.923	0.334	0.086
SD angle of the left knee	0.070	0.562	-0.330	0.715
SD angle of the right knee	-0.014	0.893	-0.023	0.382
Mean area of the body	0.771	0.123	-0.558	-0.085
SD area of the body	0.742	0.224	-0.555	-0.257
Mean height of the waist	-0.046	-0.837	-0.530	-0.053
SD height of the waist	0.295	-0.006	-0.284	0.598
Mean acceleration of the waist	0.952	0.139	-0.088	0.186
SD acceleration of the waist	0.924	0.043	0.336	-0.073
Eigenvalue	9.939	6.048	2.458	1.857
Variance (%)	45.177	72.669	83.843	92.285

Table 5. Result of PCA for motion feature values


(a) PC1 vs PC2   (b) PC3 vs PC4
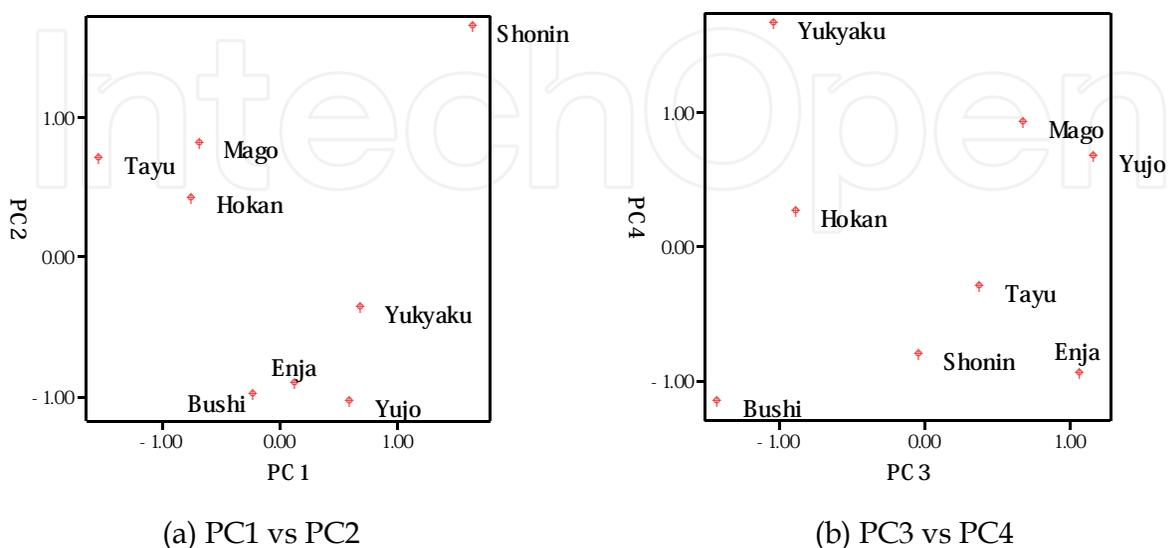
Fig. 5. Plot of PCA score for motion feature values

7. Multiple regression analysis

We investigated the regression between the impression and the physical feature values of movements. In the multiple regression analysis, we set the physical feature values obtained from our motion capture data as independent variables and the principal component scores of impressions determined by observers (for example, PC1: activity, PC2: potency, etc.) as dependent variables (by the stepwise procedure). Table 6 shows the results of the analysis, standardized coefficients ($p<0.05$) and the scores of adjusted R^2.

Dependent Variables	Independent Variables	Standardized Coefficients	Adjusted R^2
PC1 (Activity)	Mean acceleration of the waist SD angle of the right knee	0.642** 0.586*	0.840
PC2 (Potency)	SD velocity of the waist SD height of the waist SD velocity of the left hand	-0.596** -0.487* -0.344*	0.907
PC3 (Gender)			
PC4 (Complexity)	Mean height of the waist	0.770*	0.525

*…p<0.05, **...p<0.01

Table 6. Result of multiple regression analysis

As a result, three regression models with high significance were obtained, except for PC3 (significance level $p<0.05$).

From this result of our regression analysis, we found that the physical motion feature that contributes to "activity" is <Mean acceleration of the waist> and <SD angle of the right knee>. Similarly, <SD velocity of the waist>, <SD height of the waist> and <SD velocity of the left hand> contribute to the property of "potency," whereas <Mean height of the waist> is a factor of "complexity."

The result shows that impressions obtained from body motions mainly stem from motions located at some specific body parts, especially impressions concerning "activity," "potency" and "complexity," which can be estimated from motions of the waist, knees and hands. The result may apply only to the target dance motion used in this study, but it is a convincing result in that this kind of analysis can be used for extracting impressions from motion.

Although, as stated earlier, we found a factor related to "gender" in psychological experiments, we could not find any regression model for "gender" with a sufficient level of significance this time. We should have employed other physical parameters that can explain "gender" qualities, for instance, smoothness of movements, etc. This is left for further investigation.

At this time, we did not use the variables obtained by the PCA described in the previous section as the independent variables, because we could not find any significant regression model in this case. However, the regression analysis using the original 22 physical feature values is rather useful for understanding the direct relationship between physical body motions and emotions or personalities.

8. Discussion and conclusion

This research was intended to investigate the relationship between body motions and Kansei, or emotional features, conveyed by the motions. The very special dance work in which a single performer plays several different roles or characters has been used for the subject of the investigation.

Through a psychological rating experiment observing a CG character animation in an abstract representation, we found that the observer recognized the impressional factors of the body motions of each individual character or role based on four aspects: (1) activity, (2) potency, (3) gender and (4) complexity of the motions.

In this research, psychological rating experiments were done by using stick-figure CG animation characters generated from the motion captured data. Although pure physical body motion is subjected to analysis, excluding the effects of the gender of a performer, facial expressions and costumes, we found that the personalities (including gender and social class) of the characters played by the dancer were expressed well.

Also, some physical factors which contribute to the specific impressions of the motions were revealed, and a model showing the relationship between them was derived.

These results could be applied to producing a robot or CG character animation with a personality. Until now, many attempts have been made to add or enhance the emotional expression of robots using linguistic communication, some simple body motions, e.g. nodding, and facial expressions. Also, changing the design or shape of robots might be a simple way of providing a robot with a personality. However, we could not find much research on giving robots personalities through body motions.

We think that changing the personalities of robots by changing their body motions and changing the emotional expressions relayed through the robot's body motions are very promising areas for further investigation.

Future work includes (1) the study of body motions of other dance styles, e.g. contemporary dance, (2) investigation of other models besides the linear regression models, e.g. use of neural networks, and (3) use of physical feature values which take the variation in time into account.

9. Acknowledgments

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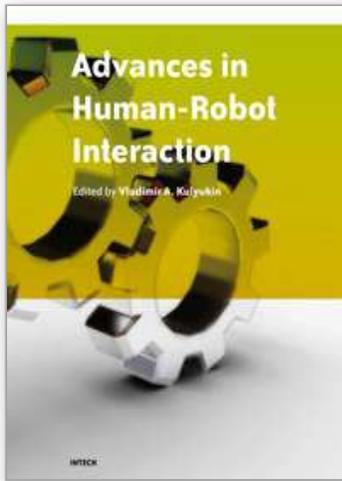
Advances in Human-Robot Interaction

Edited by Vladimir A. Kulyukin

Rapid advances in the field of robotics have made it possible to use robots not just in industrial automation but also in entertainment, rehabilitation, and home service. Since robots will likely affect many aspects of human existence, fundamental questions of human-robot interaction must be formulated and, if at all possible, resolved. Some of these questions are addressed in this collection of papers by leading HRI researchers.

How to reference

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