Quantification of Characteristic Features of Japanese Dance for Individuality Recognition

Mitsu Yoshimura Norio Mine Tamiko Kai Isao Yoshimura

School of Design and Architecture
Nagoya City University
2-1-10 Kita-Chikusa, Chikusa-ku
Nagoya 464-0083, Japan

Faculty of Engineering
Science University of Tokyo
Kagurazaka, Shinjuku-ku
Tokyo 162-8601, Japan

Abstract

Using the Eva infrared system for motion capture which outputs 3D-track data, we traced a portion of the famous Japanese dance number Fuji-Musume. A characteristic motion, or furi, and some sub-motions were extracted from the data by a devised algorithm that was applied to dance scenarios performed by an expert and beginner. From the extracted motions, index variables (indices) defined to quantify four typical forms were measured, with results indicating that they were beneficial for evaluating dance skill and distinctiveness. Another experiment compared various dances, where it was also found that the proposed indices allow comparing characteristics of motions beyond the type of dance.

1 Introduction

Individuality in human behavior has long been a target of our research interest that has included studies related to handwriting and sports techniques [1][2]. Here, however, we focus our attention on the art of Japanese dance.

While dance artists are in general reluctant to become objects of "machine processing," intense development of information technology is enabling objective study towards recognizing a number of interesting aspects of this art [3]. For example, computers can be used to evaluate the degree of skill during practice or distinguish one dancer from another. Both these tasks can to a certain degree be accomplished using advanced computer-based equipment, and in our case, we employ a motion capture system that outputs three-dimensional time series (3D-track data).

Analysis of human motions using 3D-track data is now a popular research topic. Regarding use of such data in investigating dance, Hiraga et al. [4] analyzed motions in Okinawan dancing, assuming a multivariate autoregressive model, while Osaki et al. [5] extracted primitive motions using a clustering technique associated with Oka's CDP matching method [6]. These studies were in general focused on extracting, recognizing, and understanding choreographic motion.

Our principal objective here, however, is to recognize individuality appearing in choreographic motion, and consequently, our target involves extracting certain motions that may represent a dancer's individuality, as well as how to define and measure characteristic indices that may represent the level of skill and distinctiveness. Accordingly, we used 3D-track data to define several measurable indices that quantitatively realize characteristics essential in Japanese dance, and subsequently investigated their role in an effort to better understand motion individuality.

Section 2 describes the proposed characteristic indices and Section 3 the method for extracting target motion. Experimental results are then reported in Section 4 so as to examine the meaning of the indices, with Section 5 providing concluding remarks.

2 Characteristic Indices

2.1 Data Acquisition

To obtain 3D-track data, the Eva system (Motion Analysis Corp. [7]) at Nagoya City University was used. This system incorporates six infrared cameras detecting small balls (dia., 25 mm) attached to a dancer who moves in a $10m \times 10m$ field (Fig. 1 (left)).

The marker is quite light and does not disturb dancer motion. Output for each marker is obtained in the form of $\{(x(t), y(t), z(t); t = 1, 2, \ldots\}$, where t represents the time from the start of motion and the positive direction of the x, y, and z axes in the coordinate system is set as the left-side, the upper-side, and

IEEE International Worksop on Robot
and Human Interactive Communication
0-7803-7222-0/01/$10.00©2001 IEEE

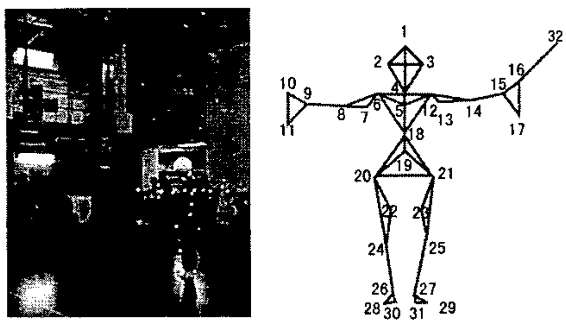

Figure 1: *The capture field (left) and positions of attached markers (right).*

the front-side of the dancer, respectively. The origin is determined by the cube unit position recognized by the cameras at the start of filming.

Thirty one markers were attached to a dancer, with an additional one attached to the tip of a hand-held fan (Fig. 1 (right)). The position of markers is identified by a number, e.g.,

No. 4: Backside of neck
No. 19: Backside of top lumbar vertebra
Nos. 20, 21: Bilateral sides of waist
Nos. 24, 25: Outside kneecaps

Based on experience, Marker 19 is considered the center of gravity of the 31 markers, and the change of each marker's position relative to Marker 19 represents twisting motion of the dancer such that horizontal movement of the dancer can be represented by Marker 19.

A sampling interval greater than $\frac{1}{240}$ s is possible, with coordinates being measured in mm. An instant in time is referred to as a frame, with the frame number indicating the time from the start of the motion. A run's output is limited to about 5,000 frames, which corresponds to 20 s at a sampling interval of $\frac{1}{240}$ s. To increase the time of the trace to 80 s, the sampling interval was accordingly set at $\frac{1}{60}$ s.

Data thus obtained consists of multiple 3D time series data with the same multiplicity as the number of markers attached to the dancer or props, being visualized as animated poses of a doll (See Fig. 2).

2.2 Japanese Dance *furi*

Japanese dancing is a player's choreographic motion led by music and/or singing. Emotional excitement is created by interactions between dancers and audience depending on the cultural background they are accustomed to.

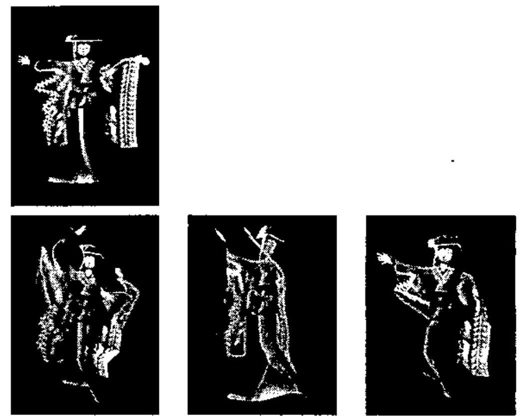

Figure 2: *A standing form in the start (upper figure) and a 3D-animation (lower three figures) by a 3DCG software.*

According to Watanabe [8], a famous Japanese dance critic, the source of emotion creation involves *furi*; a gesture implying an action such as laughing, crying, or fighting. Various categories of *furi* exist, e.g., *ateburi* is a gesture that represents the implication of a song, and *warimi* is an action performed by man representing a woman's behavior as a caricature. Any dance number is a sequence of *furi* connected by other motions such as *mai* and *odori* which allow producing continuous motion. Our intended task involves extracting various *furi* from continuous dance movement such that appropriately defined quantitative indices can be measured for extracted *furi* or submotions.

2.3 Spatial Indices

According to Nishigata [9], another famous Japanese dance critic, four forms appearing in the course of *furi* that induce profound audience emotion are *kamae*, *jyu-shin*, *koshi*, and *uchiwa*. She explains that a *furi* in conjunction with a stable *kamae* provides the audience with a stout and composed impression, while a form with a narrow *uchiwa* provides a pretty, though shy, female-like impression, one regarded as a high virtue of young females in old Japan.

To capture dance individuality via a computer, we accordingly created quantitative indices representing the above aspects (cf. Fig. 6), i.e.,

1. *kamae*: The angle between the y axis and the line

intersecting Markers 4 and 19. An index value near zero indicates a posture straightly expanded upward.

2. *jyu-shin*: The y value of Marker 19, where a small mean indicates a low center of gravity which requires discipline and in-depth training.

3. *koshi*: Angle between the y axis and the line intersecting Markers 20 and 21, where an index value in radians near 90deg indicates that the pelvis is parallel to the ground with no reclining.

4. *uchiwa*: The distance between Markers 24 and 25, where a small value indicates inward-bent knees regarded as a characteristic virtue of women in past times. It is important to mention that due to the depth of Japanese culture this corresponds to about four hundred years ago.

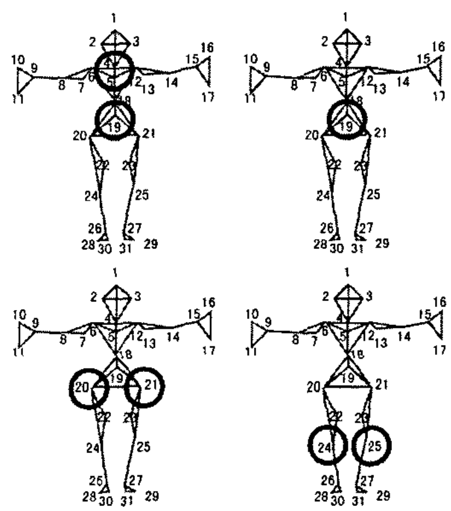

Figure 3: *Principal markers for typical index forms. Upper left: kamae, upper right: jyu-shin, lower left: koshi, lower right: uchiwa.*

2.4 Dynamic Indices

While spatial indices enable individual spatial features to be captured, capturing dynamic features is necessary as well, with speed and rhythm being paramount and leading to the following two dynamic indices:

1. *Kine-E*: A time average of the kinetic energy summed up for all markers, i.e.,

$$Kine\text{-}E = \frac{1}{T}\sum_{t=1}^{T}\sum_{i=1}^{31}\frac{Mv_i(t)^2}{2},$$

where T is the number of frames capturing a motion in question, M the mass of the dancer, and $v_i(t)$ the speed of the i-th marker. The larger *Kine-E*, the more dynamic the movement, since the speed is not by itself sufficient to measure the dynamism of movement.

2. *F-Spect*: The power spectrum in the Fourier analysis for each coordinate, which is not a value but a set of values. This is a "rhythm" index in that capturing predominant rhythms requires considering frequencies with predominant power. (See Fig. 7.)

3 Extraction of Target Motion

As a means to measure the spatial indices, target motion such as *furi* must be extracted from object data. Namely, once reference data on the target motion is obtained, method application similar to that proposed by Oka et al. [6], Osaki et al. [5], or Kai et al. [2] is possible.

This concept was applied using an algorithm described as follows. First, let the variables representing frame numbers of reference and object data be r and t, respectively. If a suitably determined warping function $t(r)$ matching these variables is found, the target motion part can then be extracted from object data as $\{x(t(r)), y(t(r)), z(t(r)); r = 1, 2, ..., R\}$, where R is the number of the last frame of the target motion in the reference data, the first frame being $r = 1$. The specific algorithm used for obtaining the optimum warping function is described in Kai et al. [2].

For algorithm application to our data, one marker must be selected as representative of motion such that correspondence is obtained between two time axes, and for this purpose the marker with the greatest speed is used. Marker 32 was the marker for *furi* extractions in trial experiments, although Markers 11, 10, or 16 were chosen for other sub-motions. When sub-motions are extracted, such as that representing fine twisting of the waist, changing the coordinate system is necessary to more easily calculate respective characteristics.

This was accomplished as follows:

1. The origin is the center M_g of gravity of Markers 19, 20, and 21.

2. The y axis is the line normal to the plane containing Markers 19, 20, and 21.
3. The z axis is the line from Marker 19 to the origin.
4. The x axis of the coordinate system is orthogonal and right-handed.

4 Experiment

A trial experiment was performed to examine the effectiveness of the proposed algorithm in (i) extracting target motions from object data and (ii) usefulness of the employed spatial and dynamic indices for capturing dancer individuality.

4.1 Method

An expert and beginner dancer performed two dance scenarios from *Fuji-Musume*. Before trial practices for obtaining object data, the expert provided reference data for *furi*'s F1-F5. In the first trial the expert played a 2-min scenario, Scen1, containing *furi*'s F1-F3, and in a similar second trial, Scen2, *furi*'s F3-F5. The beginner performed the same dance scenarios. The algorithm was subsequently applied to both trials to extract *furi*'s F1-F5, after which typical submotions T1-T5 were extracted from *furi* F1 and T1-T7 from *furi* F3 using the moving coordinate system.

Next, indices *kamae*, *koshi*, *jyu-shin* and *uchiwa* were calculated for practices as a whole, for extracted *furi*'s, and sub-motions, while *Kine-E* and *F-Spec* were only calculated for practices as a whole. To examine whether the employed indices are useful for other types of dance, they were also calculated for a practice of a dancer for Balinese (Legong), Chinese (Taichichuan), and standard ballet (Pas de deux by Chaikovskii) dancing, respectively.

4.2 Results

Figure 4 shows animated figures of extracted *furi* F1 from reference data and object data by the expert and beginner at five particular times equally distributed between the start and end of Scen1. Note that comparing the similarity among figures indicates the effectiveness of the proposed algorithm, which from a visual standpoint seems satisfactory.

Table 1 summarizes results for various cases, while Table 2 compares expert and beginner results for submotions T1 and T2, where the "# of frames" indicates the length of time for each motion.

Figure 5 shows typical extracted sub-moitons, where the left-hand side shows illustrations of submotions T2, T3, and T5 provided by the expert. The right-hand side indicates the starting point of each extracted motion corresponding to the figure on the left-hand side.

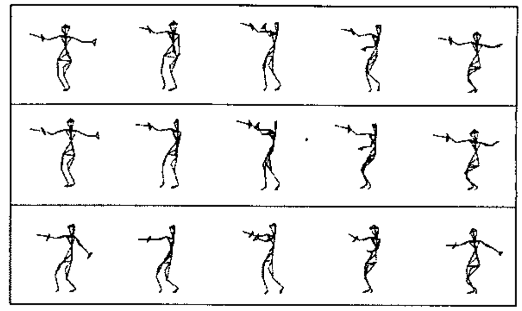

Figure 4: *Extracted furi F3 from Scen1. Shown are reference data (upper row) and object data for the expert and beginner (middle and lower row, respectively).*

Figure 6 shows time-dependent changes in *kamae* and *jyu-shin* for the expert and beginner, where the two central areas ($t1 - t2$ and $t2 - t3$) correspond to sub-motions T2 and T3, respectively.

Figure 7 shows *Spec-F* corresponding to (a) Japanese (Scen1 by expert), (b) Balinese, (c) Chinese, and (d) ballet dancing.

5 Discussion and Conclusions

5.1 Extraction of Target Motions

As shown in Fig. 4, the proposed algorithm performed well in extracting target and sub-motions from two scenarios taken from *Fuji-Musume*, which indicates that quantification of individuality in dancing is possible.

5.2 Individuality

Defining four spatial indices allowed basic quantification of target motions *kamae*, *jyu-shin*, *koshi*, and *uchiwa* which are essential features in Japanese dance. These indices clearly allowed capturing some aspects of a dancer's performance individuality.

The difference in skill between the expert and beginner can actually be seen in Table 1 in that the number of frames and Kine-E are both smaller for the beginner despite the scenarios and music being the same; a result that indicates insufficient expression of the beginner's emotion. Note that the same tendencies appear in Table 2 as well.

Table 1: *Mean (upper row) and standard deviation (lower row) of indicated indices for various cases.*

	Expert				Beginner		Bali	China	Ballet
Motion	Scen1	Scen2	F1	F3	F1	F3			
# of frames	1955	2160	480	1007	452	887	2575	6650	1125
kamae	8.1	7.1	6.5	6.9	13.5	10.0	20.1	14.4	9.1
(deg)	5.0	4.1	5.9	4.2	3.9	3.8	5.3	6.2	4.2
jyu-shin	803	804	835	807	865	866	860	858	971
(mm)	53	59	35	50	20	38	98	37	79
koshi	87.1	86.3	86.6	86.7	96.2	95.4	92.5	87.6	87.8
(deg)	2.7	2.5	1.3	2.0	0.9	1.8	3.1	6.3	14.2
uchiwa	200	201	201	202	216	218	462	518	421
(mm)	5	5	3.5	4.3	3.3	9.4	75	111	174
Kine-E	1055	1293	354	1338	248	1102	830	1330	13187

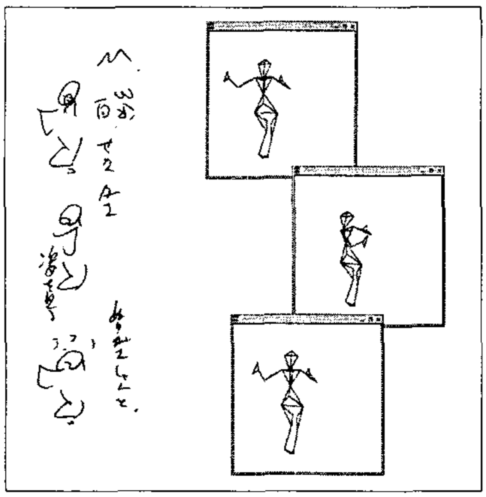

Figure 5: *Three typical sub-motions in furi F1.*

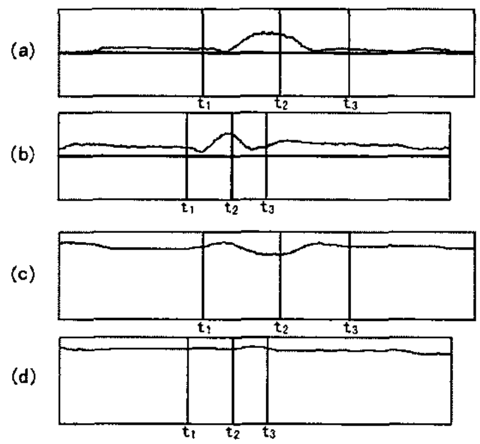

Figure 6: *Typical time-dependent changes in kamae (a, b) and jyu-shin (c, d) of the expert (a, c) and beginner (b, d) appearing in F1. t1 to t2 corresponds to T2, and t2 to t3 corresponds to T3.*

Regarding obtained index values for the target motions shown in Table 1, those of the expert dancer are comparatively smaller; a result indicating that her posture is in a low, stable, upright position with the waist line parallel to the floor. Moreover, throughout the scenario she maintains the female-like *uchiwa* pose in spite of dynamic movement.

The fact that the expert dancer almost always exhibited a higher standard deviation reflects dynamic movement which enables vivid presentation of her emotion to the audience.

As shown in Fig. 6, the movement of the expert appears wave-like, whereas that of the beginner is not even comparable.

5.3 Comparison with Other dances

The differences among dances in the case of *Kine-E* are meaningless because the scenarios were quite different. On the other, when considering the small standard deviations for Japanese dance in *uchiwa*, this indicates distinct characteristics of Japanese dance emphasizing gentle behaviors of Japanese women. Future experiments using other dance numbers are expected to confirm this finding.

Concerning the frequency characteristic of Japanese dance appearing in the first row of Fig. 7, a predominant peak in power appears in y, whereas no peaks are present in x and z; a result

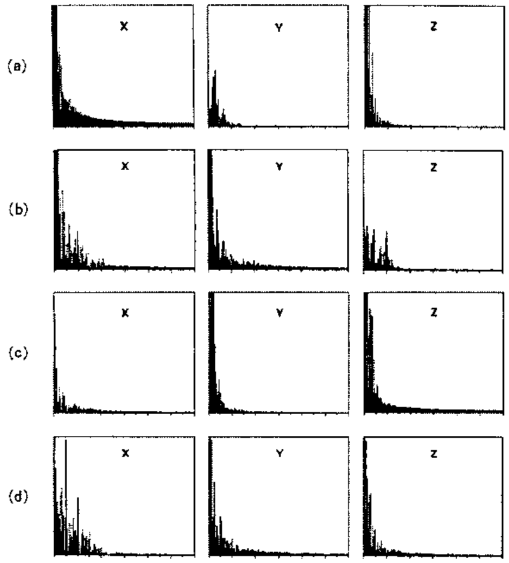

Figure 7: *Power spectrum of {x (left), y (center), z (right)} for (a) Japanese, (b) Balinese (c), Chinese, and (d) ballet dancing.*

indicating that the dancer rhythmically swings her body up and down, whereas horizontal movement is slow.

In the case of Balinese dancing, small peaks appearing sporadically indicate a characteristic feature in which slight movements rhythmically continue without stopping. The slow and composed characteristics in Chinese dancing (Taichichuan) produce frequency characteristics with no peaks, in contrast to the dynamic movement found in ballet dancing.

Acknowledgement This study was partly supported by the Grant-in-Aid for Scientific Research (C11680398) of the Japan Society for Promotion of Science.

Table 2: *Mean (upper row) and standard deviation (lower row) of spatial indices for the expert and beginner.*

Player	Expert		Beginner	
Motion	T1	T2	T1	T2
# of frames	81	89	76	53
kamae	5.6	6.7	8.6	7.5
(deg)	2.6	2.5	1.9	1.7
jyu-shin	832	806	897	855
(mm)	55.4	80.0	26.4	52.2
koshi	86.3	89.4	94.7	95.8
(deg)	1.6	2.3	1.3	0.6
uchiwa	201	203	225	225
(mm)	3.4	2.2	3.1	3.1

References

[1] M. Yoshimura and I. Yoshimura,"Off-line Verification of Japanese Signatures Based on a Sequential Application of DP-matching Method (in Japanese)," *Trans. IEICE Jpn.*, **J81-D-II**, pp. 2259–2266, 1998.

[2] T. Kai et al., "Extraction of Target Motions from a Continuous Movement Captured by an Infrared Tracing System (in Japanese)," *Proc. MIRU2000*, **Vol. I**, pp. 493–498, 2000.

[3] J. Stuart and E. Bradley, "Learning the Grammar of Dance," *Proc. 15th Int. Conf. Machine Learning*, pp. 547–564, 1998.

[4] T. Hiraga et al. "Motion Analysis of Okinawa Dance Based on a Multivariate AR Model (in Japanese)," **Tech. Rep.**, **HIP99-40**, pp. 43–47, 1999.

[5] R. Osaki et al."Extraction of Primitive Motions by Using Clustering and Segmentation of Motion-Capture Data (in Japanese)," *Jour. Jpn. Soc. Arti. Intel.*pp. 878–886, 2000.

[6] R. Oka,"Word Recognition Using a Continuous DP-matching Method (in Japanese)," *Tech. Rep. Acoustical Soc. Jpn*, **S78-20**, pp. 145–152, 1978.

[7] Motion Analysis Co. Ltd, "Reference Manual of Eva System," 1997.

[8] T. Watanabe, "Japanese Dance (in Japanese)," Iwanami Shoten, 1991.

[9] S. Nishigata,"The World of Japanese Dance (in Japanese)," Kodan-sha, 1988.