Преглед НЦД 8 (2006), 51–66

Kozaburo Hachimura
(Department of Media Technology,
Ritsumeikan University, Kusatsu, Japan)

DIGITAL ARCHIVING OF DANCING

Abstract. This paper describes our project on digital archiving of intangible cultural properties such as dance and other performing arts. We employ a commercial optical-type motion capture system for measuring accurate human body motion during dance. The acquired data have been stored for preserving precious intangible cultural properties for the future generation as well as processing human body motion by both quantitative and qualitative approaches. Processing includes retrieval and indexing of captured data, and recognition of motion. A topic of CG restoration and reproduction of a Japanese historical Noh stage and Noh plays, which can be applied to the preparation of edutainment materials, is also described.

1. Introduction

Digital archives which involve activities to preserve, for future generations, historical and cultural properties through digitization have been undertaken in various places. Planer materials, such as paintings as well as historical documents, are the fundamental subjects of digital archives. Attempts are also taking place for digitally archiving items such as archaeological artifacts and art works using three-dimensional measurements. Furthermore, in recent years, subjects of digital archives have not just being limited to such tangible cultural properties, but has also being including intangible cultural properties: namely, music, dance and theater arts expressed by human body movement.

At the Art Research Center of Ritsumeikan University, with the preservation and analysis of intangible cultural properties as our primary research topic, we are undertaking digital archiving of various materials and data associated with dance and theater arts. As for the preservation of body motion in dance, while preserving already recorded images as a film archive, we are also making video recordings of traditional theater, especially multiple angle video recording that uses multiple video cameras simultaneously. Furthermore, we have installed an optical-type motion capture system and are examining its possibilities for use in archiving and analysis of dance movements [**1**].

This paper introduces the research on digital archiving of dancing being currently conducted by the author's group and some of the related research activities conducted by other groups.

2. Dance and Motion Capture

The development of motion capture systems has enabled us to acquire time series data of three-dimensional coordinates of various body parts during body movements. Consequently, we are now able to accurately measure body motions of intangible cultural properties and to preserve resulting digital data to be inherited by future generations. Use of these data for nurturing successors of the cultural properties is also expected.

After the installation of an optical-type motion capture system at the Art Research Center, we have been using the system as a tool for archiving of dance movements. While it is necessary to have substantial training and experience for the operation of the system, in recent years the system has become easier to use due to the developments in camera and computer technologies that have made real time motion capture and simultaneous display of the motions of a CG model possible. We have already captured dances such as Noh theater, traditional Japanese dance, modern dance, ballet and ethnic dances from various regions of the world.

However, we must honestly admit that there are some problems in the recording of traditional arts such as Noh and Japanese dance using current motion capture technology: For the purpose of accurately recording three dimensional positions of various body parts, a dancer is compelled to perform under unusual circumstances in the sense that the dancer wears special body suits. This may cause a negative influence on their performance. Also, for dance archives, body motion by itself is not everything, and irrespective of the fact that the state of costumes and make-up are important, these cannot be recorded by a motion capture system alone.

Despite these controversial points, since quantitative analysis of body motion in intangible cultural properties becomes possible, there is an expectation that the essence of these arts can be delved into by combining this with the qualitative assessment that has been conducted so far.

We asked several master performers of purely traditional Japanese performing arts who have actually experienced motion capture about their impression on motion capture. While acknowledging the problems of motion capture explained above, they answerd that the measurement of this kind of objective data and the display of this by computer graphics as being of value in their analysis of their own performance. Especially they wanted to utilize it, for observing how their performance changes through aging. We understand this as being suggestive of the value that motion capture technology holds for recording, preserving and analyzing intangible cultural properties including purely traditional ones.

3. Utilization of Motion Data

The utilization of the data captured by motion capturing to produce CG animation and multimedia educational materials is a fundamental but important application.

From this perspective, the following researches are being undertaken in Japan. Literature [**2**] describes a method of segmenting a sequence of body motion of Japanese folk dance into basic primitive motions and categorizing them as primitive notation elements which are equivalent to the musical notes. New dance motion can be generated by using combinations of these “Dance notes”. Also, in literature [**3**] the simulation system of choreographing is presented. The system produces CG animation which interactively integrates the ballet's unit motion (pas) data obtained by motion capturing. Furthermore, as research from a slightly different perspective, there is a research that utilizes the dance motion capture data to make a humanoid type robot dance [**4**]. In order to do this, the motion data to be used is segmented into units of primitive motion, and then through its integration, new movements to activate the robot are produced.

With the cooperation of the Katayama-House of the Kanze school of Noh theater, we have made CG contents of some Noh plays and are also producing multimedia educational materials on Noh theater. Figure 1 shows a snapshot taken from a CG animation produced using motion captured data. Noh is an art which is highly abstract in nature. Without the knowledge of the story and the background, it is very difficult to understand the play even for adults. We produced this CG with the idea of using it for education on the Noh play. In other words, we have not captured the performance purely to use only for CG production, rather we have done this with the intent of being able to explain the background of the story more effectively through CG. This demonstrates the possibilities of application of motion captured dance digital archives.

FIGURE 1. Example of CG animation

Since it is already possible to produce three dimensional character animation from motion data using commercially available CG software, there is not much of a research perspective in this activities. However, as will be discussed later, this provides significant advantages for the publicity of the dance digital archive itself and the research results. It is also thought that this will be meaningful for the research because the process for producing high quality CG products of this kind requires good understanding of the subject art and its background, and the production experience will develop a deep knowledge for the subject art. For these reasons, we are actively conducting the production of CG contents.

For the reproduction of professional-level performing arts that were recorded by motion capture, a detailed expressive CG character alone is not sufficient. It is also necessary to prepare an environment worthy of the performance, namely, a stage and its surrounds. From this viewpoint, we are also trying to reproduce a CG Noh stage that is worthy of the CG reproduction of high-level Noh plays. Here we chose Japan's oldest Noh stage, Nishihongan-ji's "North Noh stage" (Figure 2), which was built in the 16th century and is a national treasure with extremely high cultural and historical values.

FIGURE 2. "North Noh stage" at Nishihongan-ji

For the CG modeling, we were able to use accurate drawings that were made up during the major repairs through disassembly in 1928. There were 9 sheets of drawings in total, including planar view, frontal and cross-sectional view drawings.

As can be seen in Figure 2, this Noh stage is in the open air, and although the stage is a wooden building, special protection has not been implemented. A picture of pine trees drawn on a wall of the stage is in the situation where the majority of pigment has faded away and the layout of the picture can hardly be ascertained. Because a picture of pine trees is in general one of characteristic parts of the Noh stage, the expression of this is extremely important for the reproduction of complete and high quality CG contents. This time we asked an expert in the restoration and reproduction of historical paintings to restore the picture. By tracing the marks of pine picture dimly remained, they reproduced and replicated on a small piece of wooden board about 30 cm in height. We then photographed this with a digital camera and used the image data for texture mapping.

For CG modeling and rendering, we used the software LightWave. Examples of the results of rendering are shown in Figures 3 and 4.

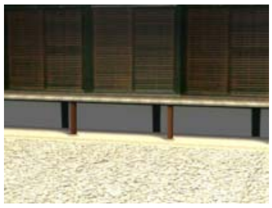
FIGURE 3. Example of rendering result (1)

Furthermore, using the produced Noh stage CG model, we attempted to produce walk through animation from the Noh performer's view point that can be derived from motion capture data. Namely, from the location of four makers attached to a player's head, we extracted the coordinates of the midpoint between the left and

Figure 4. Example of rendering result (2)

right eyes as well as the gaze direction and then used these for the production of the animation. Through our attempt to use the professional Noh performer's captured data, we are able to produce energetic and exciting animation scene from the Noh performer's view point which any audience can never experience. Figure 5 shows animation snapshots. The movement corresponding to this Figure was one of the fastest movements within the play, and (a) through (f) are the images taken at an interval of sixth of a second.

(a)

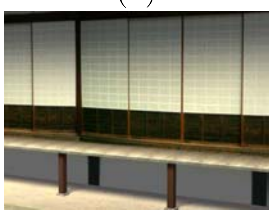


(b)

(c)

(d)

(e)



(f)

Figure 5. Snapshots of animation from the Noh performer's view point

Also, we have a system named an Immersive Virtual Environment (IVE), which stereoscopically displays three dimensional images on a large cylindrical screen. Our ultimate goal is to make the CG Noh player perform Noh play on the Noh stage in this IVE. Although still at an elementary step, Figure 6 shows snapshots of the display. In these images objects appear to overlap. This is because we photographed the screen of stereoscopic display. If one looks at this screen wearing special liquid-crystal shutter glasses, one is able to observe a lively stereoscopic scene.

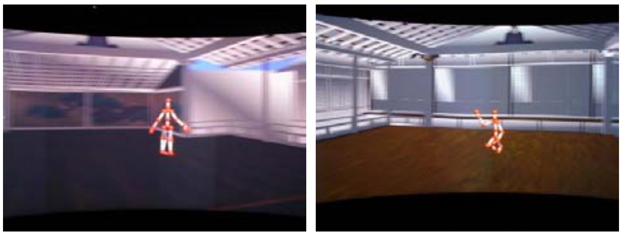


FIGURE 6. Snapshots of stereoscopic display on the IVE

Although it requires a significant amount of effort and time, if one uses off-the-shelf CG production tools, such as Maya and LightWave, one is able to produce CG contents for displaying on a personal computer without any notable difficulties. However, the production of contents to be stereoscopically viewed on the IVE used here can't be achieved using commercially available CG production tools. We need graphics programming with various techniques peculiar to the IVE sysem. This is why the status quo only goes as far as the simplistic stick-figure representation shown in Figure 6. We are now making improvements towards much more realistic expression of the stage and CG character.

4. Utilization of Labanotation

In the field of dance, methods for notating body movements have been investigated from long ago, and among such methods, a dance notation known as Labanotation has been widely used [**5**]. This is similar to musical scores, and notates movements of each body part by using graphical symbols. It uses many symbols to describe detailed body motions, and thus the score looks very complicated. As a result, it is not necessarily easy for everyone to interpret a score for the first time. However, we do not need much time to become proficient in it to some extent. Because the movements of body parts are represented by a sequence of symbols, this enables us to macroscopically grasp overall body movement once accustomed.

Today, the Labanotation, that has been used to date and was developed in isolation from computer technology, no longer has advantage over the motion capture in accuracy of recording. We have to admit this fact. However, like musical scores, it may remain important because this method is the most fundamental method for notating dance motion and is still used and well studied in today's dance community. We think that the Labanotation scores can be regarded as something that has recorded an essence of the dance or as an abstract of the dance. From this perspective, we are undertaking researches on handling Labanotation by computers.

Some researches have been conducted concerning the computerization of Labanotation. Firstly, in addition to research on a graphics editor for Labanotation [**6**], there have also been systems developed such as the LabanWriter for Mac OS [**7**], Calaban for Windows [**8**] and Led & Linter for Unix [**9**]. However, these systems only have functions to input and edit scores. They do not have any functionality to reproduce and display the body motions. There is also research being conducted on a method for transforming scores that have been edited by LabanWriter into animation of LifeForms, which is developed for dance choreographing [**10**]. However, this requires the commercial software LifeForms, and the operation of which is not guaranteed on various platforms. For this reason, one is not able to take an interactive approach where one composes the score while also visually confirming the corresponding motions, and therefore it is not suitable to use as a dance educational tool.

A couple of years ago, we have developed a Labanotation inputting and editing system named LabanEditor [**11**]. However, even using this system, one was not able to undertake interactive operation. One must still transform this into the three dimensional CG language VRML then display it on a separate viewer program. The newly developed LabanEditor2 allows us for interactive operation along with other improvements to the former version [**12**].

With LabanEditor2, because one is able to input and edit the score and then immediately display the produced movements, it is possible to interactively confirm the movements. Also with this system, it is possible to input and output in a data format named LabanXML [**12**], which is an XML (eXtensible Markup Language) representation of Labanotation score. Moreover, since LabanEditor2 has been developed using Java language, it is, in principle, not dependent on machine type and can be operated on various platforms.

Figure 7 shows a main editing window of the LabanEditor2. The score is written by placing graphical symbols in the canvas areas.

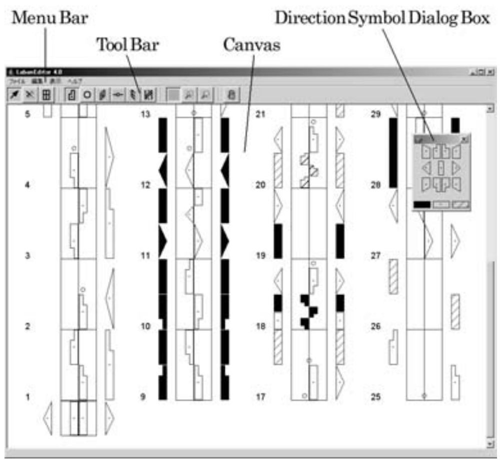


FIGURE 7. Editing window of LabanEditor2

Fundamental operations can be done by selecting from a pull-down menu within a menu bar, while other commonly used functions such as display of the symbol dialog box, scaling of the score, etc. can be operated directly via the tool bar.

As previously stated, with LabanEditor2, during inputting or editing of scores, it is possible to display corresponding body motions as three dimensional CG animation. The body motion production is made by using motion transformation templates, which are lists of Labanotation symbols against the corresponding motion. This means that in this template extent of rotation of the body part around the corresponding joint is specified for every combinations of symbols and body parts.

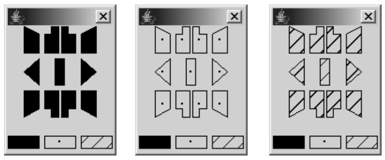


FIGURE 8. Direction symbol dialog boxes

When displaying the animation, one is able to control the display, including replaying and stopping etc. Also, the synchronization between the animation and score is indicated by displaying a horizontal red line that lies on the score and moves upwards with the passage of time.

An example of three dimensional CG body motion displayed by LabanEditor2 is shown in Figure 9. To the left is the inputted score and to the right are snapshots of the motion display results.

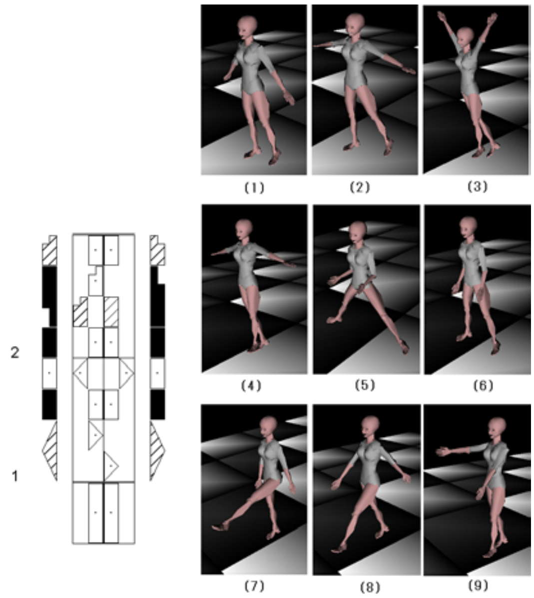


FIGURE 9. Labanotation and corresponding body motion

We are also conducting research on automated generation of Labanotation from motion data obtained by motion capturing [**13**]. We can use generated Labanotation for choreography and dance education purposes. The generated dance score data is also able to use as a summary or as an index of the original motion data. So far, we are able to verify the generation of Labanotation for simple motions. However, in processing actual dances various problems still exist, and automated processing is not necessarily easy.

5. Similarity Retrieval of Body Motion Data

By the use of motion capture systems, we have been able to capture various dances. However, as the amount of captured data continues to increase in the future, the management of these data will become a serious issue. For this reason, a database system becomes necessary for motion captured data. However, what is required here is the realization of a system with "similarity retrieval" of motion data based on the similarity between body motions rather than by just using annotation information described by character data.

There are several researches related to the retrieval of body motion data. Firstly, literature [**14**] includes the expression of the body position at a specific time by nine vectors and then determines the degree of similarity between poses by the weighted sum of the normalized correlation among the vectors. Two motions where posese with a high degree of similarity continues over a specified length of time are considered to be similar motions, and by using a time series correlation matrix the similar motions that appear within the dance are extracted. Furthermore, the literature [**15**] applies matching for positions of every body parts in order to determine the distance between body poses. Then, the minimum value of the sum of distances for all of the body parts is found, and the motion of the segment with this minimum value is retreived as the similar motion.

In comparison to these approaches, our approach is much simpler and adopts a method that directly seeks similarities among the body motion data [**16**]. In order to conduct similarity retrieval, it is necessary to determine the degree of similarity among body motion data. There are many issues about how similarity of identical body motion should be defined. For example, even in movements of walking, there are instances where you start with your right foot and instances where you start with your left foot. Also there are differences in walking speed as well as standing position and direction. Since all these are conceptually the same movement of "walking", it is possible to regard these as same movements. However, the motion capture data for these are all different. Also in dance, even though the overall body motion is the same, it is common to see variations in the speed of the motion depending on the performer. It is necessary to make possible a similarity retrieval that takes into account such differences as well as differences in body type and size.

In this research, in order to conduct matching among body motion data, we utilize the DP matching method, which is widely used in voice recognition and hand written character recognition. By this, we are able to take into account differences in motion speed. The similarity of motions is determined by calculating the distance between joints. When two body postures at any moment are provided, the distance between the body postures is defined by the sum of distances between corresponding joints. Given a continuous time series of body posture, the sum of the distances between the body postures in each moment is regarded as the distance between the body motion data.

We have developed a system that conducts motion retrieval based on the similarity between body motion data and using the matching method described above. First, a user specify the subject body motion data and then the body motion data that should be extracted from this (referred to as question data). When retrieving, comparing all corresponding joints is the standard method. However, when doing comparative study of dance, there are cases where one wishes to focus in on hand or leg movement only. For this reason, we have also made it possible to search on some specific body parts, for example only the right hand etc.

Here we explain a search example for the "Okuri" motion, which is a fundamental motion commonly found in traditional Japanese dance. Okuri has characteristics in its foot motion and along with the movement of the chest and shoulders, it is used in scenes where an impression of a lady with a prestigious presence is exressed. Figure

10 shows a partial extract from the Okuri motion data. Using this as "question data", one of the results of a retrieval directed to different motion data of the same dancer, is shown in Figure 11. It can be seen that a similar motion has been retrieved. In this case, the search was conducted with all body joints.

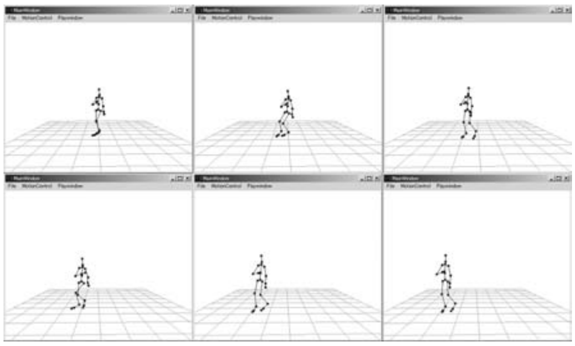


FIGURE 10. Question data

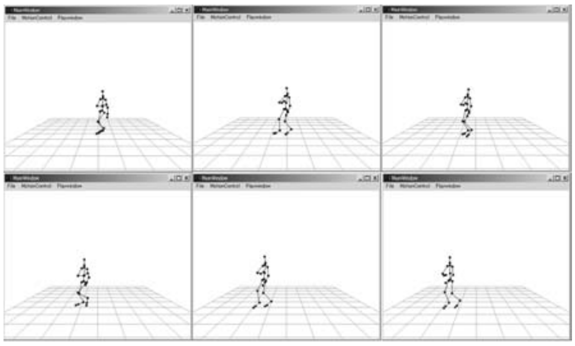


FIGURE 11. Result of retrieval

In Okuri motions, the movement of both feet is characteristic. Therefore, a search can be conducted with only the joints of both feet, that is the R/L Foot and R/L Heel as the subject of retrieval. The result is shown in Figure 12. It can be seen that although motion of both hands is different from those of the question data in Figure 10, the motion of both feet is similar to that of the question data.

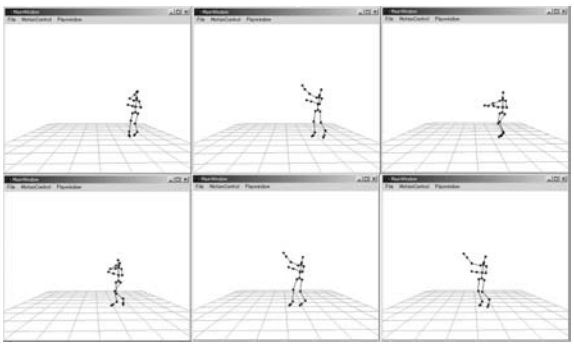


FIGURE 12. Results of retrieval using both feet only

6. Extracting Characteristic Frames

The amount of body motion data obtained from motion capturing is large and it is not easy to find and extract the necessary data from an archive. For this reason, as discussed in the previous section, the research has been conducted on similarity retrieval for body motion data. On the other hand, the automated extraction of the highlight parts or poses by which the kind and characteristics of the motion can be recognized is possible. These highlight parts extracted can be used as index information of the original motion data. Dance is an art which is expressed through the passage of time, but by extracting poses at some moments, it may be concisely expressed.

From this stand point, we try to extract some characteristics or representative poses that appropriately represent the dance from a continuum of dance motion captured data. The issue is to investigate what are the characteristic features of highlights of the dance.

As for related work, there is a research described in [**17**]. However, it looses three-dimensional information because it uses performer's silhouette images extracted from video image.

We are conducting research on extracting characteristic frames (poses) and the highlight parts from a continuum of dance motion on a macroscopic viewpoint [**18**]. Here, for every points in time, we calculate the volume of the minimum convex polyhedron (convex hull), which encompasses the performer's whole body (Figure 13). Using temporal change of this value as shown in Figure 14, characteristic poses are extracted. Figure 15 shows an example of the results. Here the candidate frames have been selected at the point in time where the volume of the convex hull exhibits local maximum.

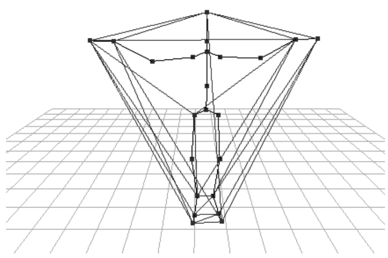


Figure 13. Body model and its convex hull

This information does not suffice for extracting appropriate characteristic frames, but we think that at least it provides with candidates for them. Then, we have to decrease the number of candidates by the simultaneous use of other information. In order to do this, we have been investigating the use of a method known as Laban Movement Analysis (LMA) [**18, 19**]. In other words, from the motion captured data, we extract the feature value calculated based on LMA. Then using this feature value, the subject body motion is evaluated for the extraction of the characteristic frames and highlights.

In recent years LMA has began to attract attention from researchers such as robotics researchers and CG animation researchers as a tool to deal qualitatively with

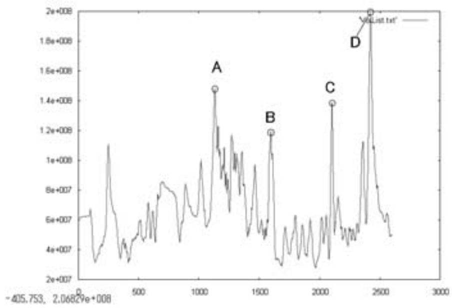


FIGURE 14. Change of volume of the convex hull

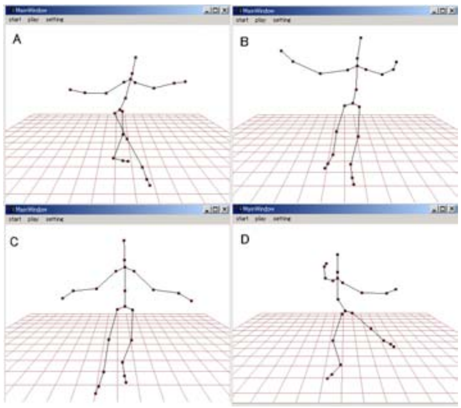


FIGURE 15. Extracted candidates for characteristic frames

what is expressed through body expression. For example, in literature [**20**], investigations are conducted to test the validity of the LMA feature values, by obtaining a correlation between LMA feature values uniquely defined and the psychological assessment value obtained form subjects who have observed the movements of a simple pet-type robot. Literature [**21**] discusses a method where the motion of CG characters is modified based on LMA parameters in order to provide the motion with expression.

In LMA, units of motion are systematically observed and expressed by the four major components: Body, Effort, Shape and Space. Currently we are focusing on three factors within Effort, i.e. Weight, Space and Time, and two factors within Shape, i.e. Shape Flow and Shaping, and we are attempting to compute the LMA feature values for body motion data. Here, only the results on Effort will be introduced.

In the literature [**20**], the Weight of Effort has been converted to a numerical value of kinetic energy per unit time. We also utilize the kinetic energy of parts of the body as the Weight feature value. As a representative marker for the movement of the whole body, a root marker which is located on the waist area is used, and in order to express the movement of the extremities of the body, markers attached to the left and right hands and toes are used.

Comparison between the results extracted by the computer program and the result obtained by an expert in LMA analysis has been made. Consequently, we found, for the Weight element, fairly a good match between parts selected by the expert and the experimental results. For the other elements, however at this stage, we don't necessarily have good results [**18**]. As for the method of calculating the feature values, we have to conduct more detailed experiments and evaluations.

7. Quantitative Analysis of Dance

Quantitative analysis in dance motion includes, for example, comparison of the body motions of experts and novices and quantitatively showing the differences between them. By doing quantitative analysis of motion capture data, we investigate issues of from what kinds of poses and movements does the skillfulness or the abundance of expressiveness are formed. Of course, the parts of body and the feature values to be focused may differ depending on the category of dance. We have been investigating the possibility of quantitative assessment by extracting characteristics of, for example, movement of a waist or hands etc.

In literature [**22**], indices for spatial characteristics were defined for the fundamental movements composing traditional Japanese dance, and analysis of how these differ between experts and novices was conducted. Also, the differences in the frequency characteristics of trajectories of joints depending on the type of dance were shown. More developed research results can be found in [**23**]. It utilizes indices about the amount of the movement of a body and spectral component obtained by Gabor transformation. It was verified that these indices expressed differences in proficiency and gender.

In order to conduct quantitative analysis of dance proficiency, it is necessary to make clear on which part of the body we should focus. This depends on the category of dance. At present we are at an initial stage where various trials are undertaken. We expect that through the integration of these results generalization will be made possible.

Literatures [**24, 25**] are based on the systematic Japanese dance research outcomes of a dance researcher who primarily undertook a research from a qualitative perspective. Those tried to verify these outcomes through physical and quantitative data analysis using motion capture. Literature [**24**] focuses on fundamental motions Okuri that are used for feminine expression. Quantitative analysis is undertaken of the motions that give impression of a prestigious lady, and it was quantitatively verified that Okuri is learnt on a step by step basis. Also, literature [**25**] conducted similar analysis of the Okuri movement that is categorized as a descriptive motion.

Furthermore, in literature [**26**], using motion data acquired from the dancing of multiple performers, experiments on whether the type of Okuri motion and the performer could be recognized were conducted. In order to do this, what kinds of feature values have to be extracted from the motion data was examined. For recognition, methods used in the recognition of handwritten characters were utilized. It was realized that good results were obtained by the use of the proposed feature values.

These researches are still in the initial stage, and the future issue is how to generalize this approach through statistical analysis based on more sample data for performers and motions.

8. Qualitative Analysis of Dance

A person watching dance receives various impressions from the performer's body motion. In effective communications among humans, and also between human and robots in the future, this kind of nonverbal information related to impression or emotion is important. A Japanese word "Kansei", whose meaning is close to sensibilities, has been used to express human's receptivity of information related to impression or feelings.

As for the association between body and Kansei, many researches have been conducted on facial expression. However, although research on Kansei generated by body movements is an important and interesting issue, we can find very few reports on this topic.

In literatures [**17, 27, 28**] , they are trying to demonstrate the relationship between dance body motion and the impression arising from the motion. When doing this they extracted the physical values of movement through analysis of silhouette images from video image taken from directly in front of the performer. However, this method discards the three dimensional information.

As for the association between dance body motions and the Kansei information obtained when observing these motions, firstly we conducted fundamental research based on psychological experiments using video image [**29**]. Taking these results into account, we are also undertaking similar investigations of the association with some physical feature values acquired from motion capture data [**30**]. Here, we conducted experiment about association of the movement and the mental image triggered by the movement. We utilized the body motions known as "Matsumoto's 7 motives" [**31**] that had already empirically demonstrated the association between the induced mental image and the movements.

In [**30**], as independent variables for regression analysis, five values are extracted from motion captured data, namely, mean and standard deviation of speed of the root marker, the height of the root marker, the sum of kinetic energy values at each body part, and lastly the sum of areas produced by triangles connecting five markers at body extremities and the root marker, which indicates openness of the body. On the other hand, the qualitative Kansei measures obtained when seeing the movement were taken as the explanatory variables. Then the relationship between these variable was derived by a multiple regression analysis. The results showed that the multiple regression model with the physical parameters described above as independent variables was valid for Kansei measures of "happy", "lonely", "solemn" and "dynamic".

9. Conclusions

The topics on digital archiving of dancing by using motion capturing, the use of captured data in analytical research of dance and the application of motion data being undertaken by our group have been introduced. In addition to what has been described here, we are also conducting a research on the development of a dance training support system that utilizes virtual reality technology [**32**].

As for dance motion analysis, we are at a stage of investigations from various perspectives and the results are still unsatisfactory. However, rather than just limit ourselves to the recording and preserving of dance motion, we would like to investigate the "aesthetics of dance" by conducting a detailed examination of both Kansei (sensibility) information processing and numerical processing.

Acknowledgements: Our research has been partly supported by the 21th Century COE program "Kyoto art entertainment innovation research" and the

Grant-in-Aid for Scientific Research, the Ministry of Education, Science, Sports and Culture, No.16300035, 2004.

References

[1] Kozaburo Hachimura: *Dance and Computer Technology – Use of Motion Capture System and Labanotation*, System, Control and Information, in Japanese, Vol.46, No.8, pp.490–497, 2002.

[2] Takashi Yukawa, Takaaki Kaiga, Kazuo Nagase, and Hideo Tamamoto: *Human Motion Description System Using BUYO-FU*, IPSJ Journal, in Japanese, Vol.41, No.10, pp.2873–2880, 2000.

[3] Asako Soga, Bin Umino, Takami Yasuda and Shigeki Yokoi: *A System for Choreographic Simulation of Ballet Using a 3D Motion Archive on the Web*, Articulated Motion and Deformable Objects 2004, LNCS 3179, pp.227–238, 2004.

[4] Atsushi Nakazawa, Shinichiro Nakaoka, Shunsuke Kudoh, and Katsushi Ikeuchi: *Digital Archive of Human Dance Motions*, Proc. VSMM 2002, 2002.

[5] Ann Hutchinson: *Labanotation*, Theatre Arts Books, 1977.

[6] M. D. Brown, S. W. Smoliar: *A Graphics Editor for Labanotation*, Computer Graphics, Vol.10, No.2, pp. 60–65, 1976

[7] LabanWriter Homepage, http://www.dance.ohio-state.edu/labanwriter/

[8] http://www.bham.ac.uk/calaban/frame.htm

[9] LED & LINTER: *An X-Windows Editor/Interpreter for Labanotation*, http://www-staff.it.uts.edu.au/ don/pubs/led.html

[10] Ilene Fox: *Documentation Technology for the 21st Century*, World Dance 2000 Academic Conference: Papers and Abstracts, pp. 137–142, 2000

[11] Kazuya Kojima, Kozaburo Hachimura and Minako Nakamura: *LabanEditor: Graphical Editor for Dance Notation*, Proc. IEEE ROMAN 2002 Workshop, pp.59–64, 2002.

[12] Hiroyuki Kobayashi, Kozaburo Hachimura, Minako Nakamura, and Koji Shibano: *A System for Inputing and Editing Labanotation Dance Score and Displaying Dance Movement Based on XML Description*, in Japanese, IPSJ Symposium Series, Vol.2004, No.17, pp.237–244, 2004.

[13] Kozaburo Hachimura and Minako Nakamura: *Method of Generating Coded Description of Human Body Motion from Motion-captured Data*, Proc. IEEE ROMAN 2001 Workshop, pp.122–127, 2001.

[14] Koji Kawashima and Takeshi Shakunaga: *Dance Motion Analysis based on Furi Segment Extraction*, in Japanese, IPSJ SIG Technical Report, CVIM-137, pp.77–84, 2003.

[15] Takeshi Yabe and Katsumi Tanaka: *Similar and Dissimilar Retrievals of Human Motion Data by its Multistream Nature*, in Japanese, IPSJ SIG Technical Report, Database Systems-119, pp.285–290, 1999.

[16] Nobuharu Takahashi, Kozaburo Hachimura, and Mitsu Yoshimura: *Similarity Retrieval of Motion-captured Dance Motion Data*, in Japanese, IPSJ Symposium Series, Vol.2003, No.21, pp.31–38, 2003.

[17] A. Camurri, P. Coletta, B. Mazzarino, R. Trocca, and G. Volpe: *Improving the man-machine interface through the analysis of expressiveness in human movement*, Proc. 2002 IEEE RO-MAN conf., pp.417–421, 2002.

[18] Kozaburo Hachimura, Katsumi Takashina, and Mitsu Yoshimura: *Analysis and Evaluation of Dancing Movement Based on LMA*, Proceeding of the 2005 IEEE International Workshop on Robot and Human Interactive Communication, pp.294–299, 2005.

[19] Jean Newlove and John Dalby: *LABAN for all*, Nick Hern Books, 2004.

[20] Toru Nakata, Taketoshi Mori, and Tomomasa Sato: *Analysis of Impression of Robot Bodily Expression*, Journal of Robotics and Mechatoronics, Vol.14, No.1, pp.27–36, 2002.

[21] D. Chi, M. Costa, L. Zhao, N. Badler: *The EMOTE Model for Effort ad Shape*, ACM SIGGRAPH'00 Proceedings, pp.173–182, 2000.

[22] Mitsu Yoshimura, Yumiko Sakai, Tamiko Kai, and Isao Yoshimra: *A Trial for Identifying and Characterizing Typical Parts of Japanese Dancing*, in Japanese, The IEICE Transactions on Information and Systems, PT.2, in Japansese, Vol.J84-D-II, No.12, pp.2644–2653, 2001.

[23] Mitsu Yoshimura, Hideki Murasato, Tamiko Kai, Akira Kuromiya, Kiyoko Yokoyama, and Kozaburo Hachimura: *Analysis of Japanese Dance Movement Using Infrared Tracing System*,

The IEICE Transactions on Information and Systems, PT.2, in Japansese, Vol.J87-D-II, No.3, pp.779–788, 2004.

[24] Yuuka Marumo, Mitsu Yoshimura, Kazuya Kojima, and Kozaburo Hachimura: *Analysis of the Primitive Motion "Okuri" in Japanse Traditional Dancing Characteristic for Young Women*, in Japansese, IPSJ Symposium Series, Vol.2003, No.21, pp.39–46, 2003.

[25] Mitsu Yoshimura, Yoshifumi Nakamura, Kozaburo Hachimua, and Yuuka Marumo: *Feature Analysis of the Primitive Motion Okuri in Japanese Traditional Dance*, in Japanese, IPSJ SIG Technical Report, 2004-CH-61, pp.41–48, 2004.

[26] Mitsu Yoshimura, Kazuya Kojima, Kozaburo Hachimura, Yuuka Marumo and Akira Kuromiya: *Quantification and Recognition of Basic Motion "Okuri" in Japanese Traditiona Dance*, Proceeding of the 2004 IEEE International Workshop on Robot and Human Interactive Communication, pp.205–210, 2004.

[27] Masayuki Inoue, Yuichi Iwadate, Ryotaro Suzuki, Mariko Shiba, and Makoto Tadenuma: *Relationship between Impression and Body-Movements in Dance Scenes*, in Japanese, ITE Technical Report, Vol.25, No.35, pp.61–66, 2001.

[28] Antonio Camurri, Shuji Hashimoto, Kenji Suzuki, and Riccardo Trocca: *KANSEI Analysis of Dance Performance*, IEEE International Conference on System, Man and Cybernetics, pp.IV-327–332, 1999.

[29] Mamiko Sakata, Kozaburo Hachimura, Yuuka Marumo: *The Extraction of KANSEI Information from Body Movement*, in Japanese Traditional Dance, in Japanese, IPSJ SIG Technical Report, 2003-CH-60, pp.65–72, 2003.

[30] Mamiko Sakata, Yuuka Marumo, Kozaburo Hachimura, Kazuya Kojima, and Mitsu Yoshimura: *An Attempt to Process KANSEI Information Found in Physical Movements in Japanese Traditional Dance – Measurement and Analysis Using Motion Capture*, in Japanese, IPSJ SIG Technical Report, 2004-CH-61, pp.49–56, 2004.

[31] Mamiko Sakata, Mariko Shiba, Kiyoshi Maiya, and Makoto Tadenuma: *Human Body as the Medium in Dance Movement*, International Journal of Human-Computer Interaction, vol.17, no.3, pp.427–444, 2004.

[32] Kozaburo Hachimura, Hiromu Kato and Hideyuki Tamura: *A Prototype Dance Training Support System with Motion Capture and Mixed Reality Technologies*, Proceeding of the 2004 IEEE International Workshop on Robot and Human Interactive Communication, pp.217–222, 2004.

Ritsumeikan University, Kusatsu, Shiga 525-8577, Japan