KANSEI Analysis of Dance Performance

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ABSTRACT

We propose a method to realize extractions of emotional information from human gestures in real time. The basic ideas of understanding the human motion is based on Rudolf Laban's theoretical work.
The system we developed consists of two parts: (i) image processing, and (ii) motion analysis. The former part works to obtain human movement by using two color CCD camera, while the latter is involved in mapping physical parameters onto emotional information.. We are trying to realize a sort of "KANSEI extractor" as the last goal. Human can understand the emotional mode, such as happy, angry and sad, in which mode the actor performs. It seems that human movement carries emotional information although it is difficult to express the emotional effects with particular physical parameters. From this point of view, we aim to extract emotional information in dance performance with the aid of computer system based on Laban's theory of movement.
In our proposed method, human motions are mapped onto low-dimensional parameter space in real time introducing two spaces: the general space and personal space.

1. INTRODUCTION

In communications between humans, the role of "KANSEI" (emotional) information is as important as logical information. The Japanese word "KANSEI" is used to express some terms like feeling and sensibility [1][2]. In this work, we try to develop a kind of extractor of KANSEI-level information with the investigation of human movement. The focus differs from other existing systems that pay attention to gesture recognition from a gesture vocabulary. We focus on the difference of intentions between two performances of the same fragment.
Some of the key concepts we are using in the exploration of human motion are taken from a basic works of Rudolf Laban (1879-1958) [3][4]. One of the most important approaches we sketch concerns his theory of movement called Theory of Effort.
We can regard the KANSEI information processing as a sort of code-decode problem. The message to be encoded is the in the KANSEI space, while the media is given in the physical space. The receiver has to be able to decode the KANSEI information from the physical signals he receives. The decoding process can be performed in two parallel ways: the direct decoding of the perceived physical data and the logical decoding through the symbolic interpretation the perceived signals.
Dance performance is an ideal case study in which an artist tries to communicate his KANSEI through movement. Laban method of observation and analysis is an attempt to extract symbolic information from movement performances in order to interpret intentions. This makes Laban's "Effort theory" an interesting tool to accomplish the task of decoding the KANSEI Information carried by movement.
The authors have been interested in interaction metaphors such as multimodal interaction system including emotional affects [5] in interactive dance/music systems. The basic study has been reported about the recognition system of several different style of dance performance [6]. We have already introduced a gesture interaction system based on video camera [7].
Laban introduced the notation method known as "Labanotation". By using the notation, it is possible to record a variety of human motion. It should be noted that the Labanotation is different from other similar works. (ex. Benesh Notation based on classical ballet). Labanotation is limited not to a singular, specific style of dance but concerning every kind of human motion.
With regard to Laban's work and his theory, from the scientific point of view, several attractive works have been done, for example, a platform of human-robot interaction has been developed in order to apply Laban's theory to movement of mobile robot [8].
This paper mainly consists of three parts. Firstly, we introduce the Laban's theory of effort with a method for extraction of *Labanian* parameters. Secondly, we discuss the description of space of human movement: *general space* and *personal space* with some experimental results. This also includes the system implementation and software architecture. Finally, we report the evaluations through some experimental results, conclusions and some issues of future work are presented.

2. LABANIAN PARAMETERS

Some of the key concepts we are using in our exploration of human motion intention are taken from Rudolf Laban's work [4]. In his theory of effort, he points out the dynamic nature of movement and the relationship among movement, space, and time. Laban's approach is an attempt to describe, in a formalized way, the characteristics of human movement without focusing on a particular kind of movement or dance expression. Effort theory principles can be applied to dance and to everyday work practices.
The basic concept of Laban's theory is effort that is a property of movement. From an engineering point of view we can consider it with a vector of parameters that identifies the quality of a movement performance. The most important concept is to describe the quality of movement. Theory of effort is not concerned with degrees of joint rotation or moment directly, but it considers movement as a communication media and tries to extract parameters related to the its expressive power. During a

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movement performance the vector describing the motion quality varies in effort space. Laban studies the possible paths followed by this vector and the intentions they can express. Therefore variations of effort during the movement performance should be studied.

2.1 Effort Space

Laban indicates 4 components that generate what we call "effort space": space, weight, time and flow.
Each component is measured on a bipolar scale, in this way every component of effort space can have binary values to represent opposite quality.

Axes	Indulging Effort	Fighting Effort
Space	Direct	Flexible
Time	Sustained	Quick
Weight	Light	Strong
Flow	Free	Bound

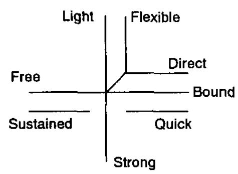


Table 1. Efforts table and symbol expression

Laban's basic theory considers the first 3 factors to develop a description system for human movement.
In this way we can identify 8 possible combinations of the space, time and weight factors, corresponding to states that the movement can assume in its developing.

Space: Regarding space, Laban says "... whenever the body moves or stands, it is surrounded by space. Around the body is the sphere of movement, or Kinesphere, the circumference of which can be reached by normally extended limbs without changing one's stance, that is, the place of support..." (R. Laban, 1963: p. 85). The Kinesphere is also referred to as personal space, while the whole space surrounding the Kinesphere (i.e., the environment in which the act of movement is taking place) is referred to as general space. When the body moves in space the Kinesphere follows it, so the study of movement can be divided in two main branches: the movement of the Kinesphere in general space and the movement of the limbs inside the Kinesphere. The approach that we use follows this method. A movement, in both kind of spaces, will follow a definite direction or a sequence of different directions. If the movement follows those directions smoothly the space component in effort space will be flexible, while if it follows them straightly it will be marked as direct.

Time: Laban considers two aspects of time: an action can be sudden or sustained, which allows the binary description of the time component of effort space. Moreover, in a sequence of movements, each of them has a duration in time, the ratio of the duration of following movements gives the time-rhythm, as in a music score.

Weight: Weight is a measure of how much strength and weight is present in a movement, so in pushing away an heavy object it will be necessary to use body weight in order to succeed.

Flow: Flow is a measure of how bound or free appears a movement or a sequence of movements.

3. GENERAL SPACE AND PERSONAL SPACE

We discuss two effects for effort of movement: general space and personal space. In the present work, we apply two kind of approaches, direct one and indirect one. With regard to the investigation of general space, we try to seek indirect relationship between physical parameters and KANSEI parameters. In other words, the analysis is based on logical term. While, the investigation of personal space, the direct relationship between physical parameters and KANSEI information is the term of analysis.

3.1 Investigating General Space

The experiment we attempted is targeted at studying some of Laban's parameters of body movements in general space. From this point of view human body movement can be modeled as Kinesphere movement in space. The techniques developed are, however, general because they can also be applied to the study of movements of limbs inside the Kinesphere.
Laban deems that a movement performance is composed of a sequence of movements executed in 8 main directions generating from the center of the body:
forward (f), backward (b), left (l), right (r), left forward (lf), left backward (lb), right forward (rf) and right backward (rb).
"The movement begins with the departure from one point in space and continues via one or several more until the terminal one is reached. Each stretch between the points takes a certain length or stretch of time".
Every movement sequence is characterized by two factors: the shape created by stretches of spaces and the rhythms created by stretches of time. This experiment is aimed at finding stretches in space and in time extracting the movement component along the 8 main directions introduced by Laban.

We used a CCD camera put on top of the stage and red LED as a makers on the body of the subject to record his movements. The files with the collected data are fed to a software we developed in order to analyze human movement. All the algorithms used have been realized in real time. This means that they use local or past data in order to perform their tasks. A set of test movements has been performed with different velocities and expressive intention:

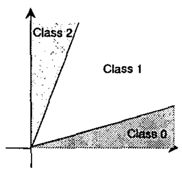
- along the main diagonals,
- along the borders of the square stage,
- walking in circle with varying velocity
- proceeding jumping from point to point as drawing Z shape with sudden movements.

An algorithm that permits to extract reliable data about the shape of the trajectory, even with high level noise, has been applied to the data. It is a new algorithm based on knowledge of the physical nature of movement and the kind of distortions that a marker and a camera may introduce in the samples.
From this filtered data, 2 basic parameters were extracted.

(i) velocity
(ii) differential dx/dy
(where x and y are the perpendicular axes that describe the 2D space in which the subject is moving. In case that small dy we use dy/dx instead of dx/dy.)

Using dx/dy allows us to extract what Laban calls "stretches in space".

The differential data dx/dy or dy/dx are classified based on their value. We can have three classes



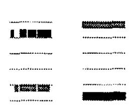
CLASS 0
ABS(differential) <= tan $\pi/8$
CLASS 1
tan $\pi/8$ < ABS(differential) <= tan $3\pi/8$
CLASS 2
ABS(differential) > tan $3\pi/8$

Figure 1. The classes of spatial direction

Class 0 represents vertical (horizontal) or almost vertical (horizontal) directions. *Class 1* represents movement along the main diagonals. *Class 2* represents horizontal (vertical) or almost horizontal (vertical) directions.

Thus we can get the first classification of usage of the 8 main directions of movement. We assign a state to the sampled data based on the class of dx/dy and dy/dx, frame by frame. A change of the state indicates a change of the direction of movement to start a new movement. We can, in this way, study Laban's space rhythm, because we can obtain data on the use of directions in space performed by the dancer. At the same time, the study of the sequence of duration of various stretches in space leads us to study Laban's time rhythm.
As the second step we studied the variations of velocity during a stretch in space identified by our algorithm. This permits us to understand if the time component of effort is sustained or sudden. If we have a sequence of stretches in space during which velocity never falls to near zero but is maintained high, then we have a sustained time. The same is true if a stretch in time lasts for several seconds.

Notation: The program developed uses a graphical notation to show the data about the localized stretches in space. It draws a sort of score with three lines. Each line represents a class of the differential dx/dy or dy/dx. Both of them are plotted with different colors (blue and red). Usually the two differentials cannot be in class 0 at the same time. But if one is in class 0 (the lowest values), then the other must be in class 2 (highest value), and so we have a horizontal or vertical stretch. if they are in class 1 at the same time we got movement along the diagonal. Due to the noise and quantization error, we may have mixed cases. The program recognizes the state of movement with two variables, the class of dx/dy and the class of dy/dx. A stretch in space is a sequence of samples for which the state remains the same.



(a) (b)

Figure 2. Indication of space stretch horizontal (a), and vertical (b)

We introduce two different examples of analysis performed on the movement performance.

Sudden-Straight Movements: Figure 3 shows an example of data visualized by our application. On the right there is a plot of the trajectory of the body during the performance. The line with dots is the unfiltered trajectory, while the one with crosses is produced by the filtering algorithm. On top left a window displays the velocity calculated from both the trajectories and smoothed with a low-pass filter. The lower curve is related to the filtered trajectory.
On the bottom left we have the directions score. Using the notation introduced above is easy to localize horizontal or vertical stretches of movement and notice a preference of the performer for vertical movements. It is also interesting to note that during each stretch in space, the velocity follows a typical curve, and the maximum velocity is almost in the middle of the state. One exception is the central vertical stretch where we can see two velocity peaks. This corresponds to the fact that the dancer is moving along the same direction (vertical) but first in one direction and then going back.

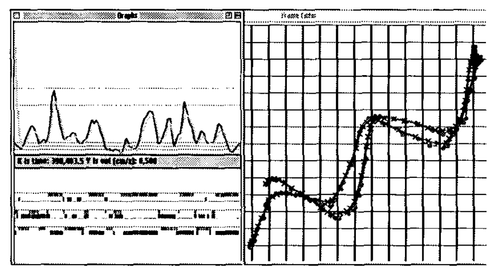


Figure 3. Visualization of sudden-straight movement

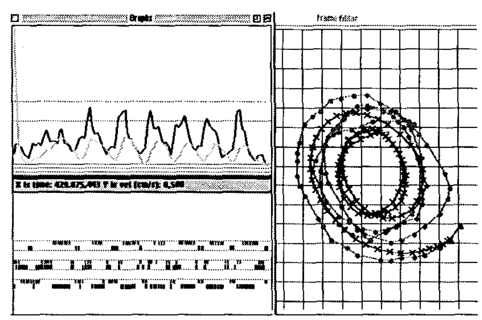


Figure 4. Visualization of circular movement

Circular Sustained Movements: Figure 4 displays an almost circular trajectory. The performer went on following this trajectory in a continuous and sustained way. It is again possible to detect a preference for vertical directions (as is apparent from the fact that the circles are not perfect) and to identify directions in space from the direction score/state diagram and notice that the velocity curve has got similar shape during all the stretches.
We will work to automatically classify this parameter.

Potential Field in General Space: While the first method introduced focuses attention on the directions used by the performer, the second method studies the zone of the stage used. The basic idea is that the information that movement can express may be varied by the position in which the performer is located. An example may be the gestures of a person that is really angry. Her gestures will have a certain rhythm and extension in space, but the effect on the person that is looking at will be different depending on the distance maintained. The same holds true for a dancer on a stage. He will use different zone of the stage to express different emotional content. Those zones may be of two types:

Natural zone: it is a zone whose expressive contribution to the performance depends just on its position. For example movements performed in the center of the stage, on the border near the viewer, in a corner far from the viewer will have different expressive power.

Artificial zone: it is a zone whose expressive contribution is modified by some external factor, for example a spotlight or a particular arrangement of the stage (i.e. lights, scenography).

To study this we create a virtual grid mapped on the stage, the grid is simulated in a computer system that detects the position of the dancer. The grid is composed by several active cells. When a dancer passes or stops on a cell it receives an excitation signal and changes its internal state (in the current implementation a counter is incremented as long as the excitation lasts). While the dancer does not use the zone mapped on the cell it does not receive signals (and in the current implementation the counter starts to decrease). With this approach the grid creates an active map of the zones of the stage that the dancer is using. Each cell has also got an internal state representing its "expressive" value during the time. This valued is computed using a potential field that models the shape of the stage and the presence of spotlights. The zones near the walls of the stage have got a low potential value, while zones pointed at by spotlights have a high potential value.
We can model different spotlights and potential field based on the necessity of the performance. By now the system can only study the zones that has been used and so evaluate the time spent in zones with high or low potential.

The idea of potential field in general space is to add an effect at the position of human. While a human moves in general space where he can perform, he receives an effect with regard to the position where he plays on the stage. We prepared a spotlight on the stage. Therefore, if dancer wants to perform at the space where has strong attention (i.e. in front of observer) where spotlight is attended. From this point of view, we set a potential field on the stage as shown in figure 5.

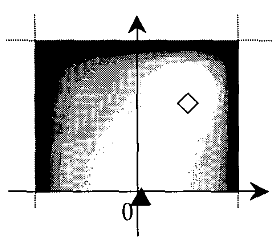


Figure 5. Coordinate of potential space

In above figure, let ◇ and ▲ denotes the position of spotlight and observer, respectively. Here coordinates ◇ (1,2), and ▲ (0,0) are placed on the space where is surrounded with walls. The plotted line shows wall and the functions are denoted as: y = 3, x = ±2. The brightness of each point shows the value of potential: white point is higher, while black one is lower. It is defined as following function:

$$\phi(r) = \frac{e_a}{|r_a - r|} + \frac{e_s}{|r_s - r|} + \frac{-e_w}{|r_w - r|}$$

Where e_a, e_s, e_w is effect of audience, spotlight, and wall, respectively, that defined as constant parameters. Figure 6 shows different potential spaces according to the position of spotlight.

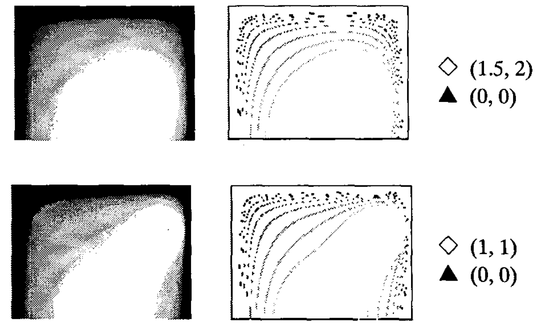


Figure 6. Examples of Potential Spaceg

3.2 Investigating Personal Space
The analysis of personal space is to extract parameters that have characteristics of KANSEI information. In this paper, we focus on not the details of human body parts, but on the whole motion. The human is surrounded by space around his body. As Laban describes, the space is the circumference of which can be reached by normally extended limbs without changing one's stance. Thus, when human steps outside the borders, he creates a new one from the new stance. In other words, he transfers his personal sphere to another place in general space.
Based on this idea, we would like to begin with the analyze the personal space. We try to detect the change of the space with time where human moves in front of audience on the stage.

System Overview: Figure 7 shows the overall of developed system. In the present work, image data is obtained by color CCD camera at the rate of approximately 10 frames per second.

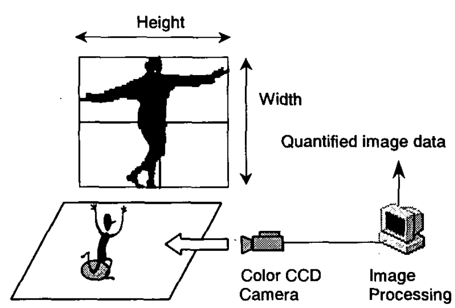


Figure 7. System overview

At first, the frame image buffers of color pixels is stored, and these input buffers from video is quantified into two-level by using the difference between the current target and the background in real time. In the meantime, noise elimination processing is done with the threshold based algorithm. By using these filters, we can detect whole human body figures at each frame.

Then, we extract the motion parameters as shown in Table 1.

W	Width	The length of width
H	Height	The length of height
S	Space	W×H (width × height)
R	Ratio	W/H (width : height)
V	Volume	Occupied ratio of the space S

Table 2. Specific motion parameters

As shown in Figure 7, quantified image data of human motion is surrounded with a rectangular form. Let W and H denote the length of width and height, respectively. Then, S and R are obtained by the product and ratio of them. The volume represents the value of size where human is occupied in the above rectangle. In addition, since these parameters change with time, we calculate the difference between current and previous frames as ΔW, ΔH, ΔS, ΔR, and ΔV.

The typical variation of each parameters is illustrated in following Figure 8(a)-(c). In this experiment, the movement is obtained by the performance of choreographer Giovanni Di Cicco. The stage where he perform is set at 4m x 3m. The duration of movement sequence is 40 second.

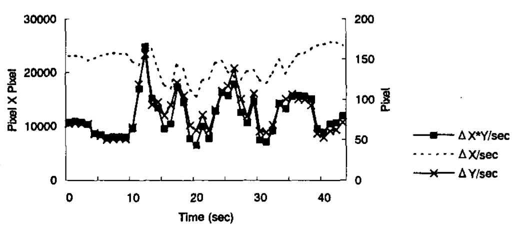


Figure 8(a). The variation of ΔW, ΔH, and ΔS

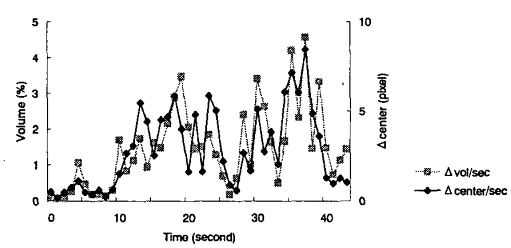


Figure 8(b). The variation of ΔV, ΔC

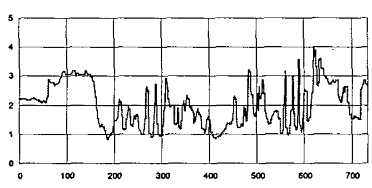


Figure 8(c). The variation of W:H

The characteristics of the performer can be read from these figures. X-axis represents time at second, while Y-axis represents each value. First graph represents the variation of ΔW, ΔH and ΔS. It contains two coordinate axis: left y-axis according to ΔW and ΔH, while right y-axis according to ΔS. In this performance, the variation of height can be seen much more related to the one of space than width.

On the other hand, the variation of W:H shows us important features. This form would represent a sort of characteristics of dance sequence. For example, while the curve is enough smooth, it shows that less change of the motion space. Instead, periods where there are lots of peaks, it means aggressive change of the motion space.

Characteristics of dance performance: In order to extract characteristics of dance performance, we did another simple experiment with particular sequences of ballet performance "The Sleeping Beauty" (*ballet, Bolshoi Theater*). At the first part of the ballet, there is a scene that five fairies appear on the stage. The five dancers play a role of each fairy, called fairly of tenderness, happiness, generosity, serenity, and courage, respectively. Therefore, the dancer is expected to express these emotional modes of dance effectively.

The left window of Figure 9 shows original image data. While, the right window shows the quantified image data where the rectangle inside right window represents the motion space.

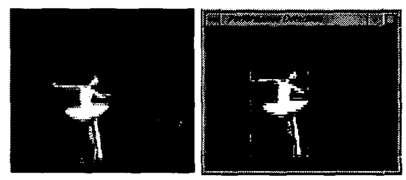


Figure 9. Motion detection windows

To compare with each dance performance, we introduce the following radar graph. Because of the different duration among these five dance sequences, we applied normalization method to parameters. Each ΔW and ΔH are divided by W and H, respectively for spatial normalization. In addition, each value is the average of time duration, including consideration of average deviation. According to this method, these five dance sequences are shown in Figure 10.

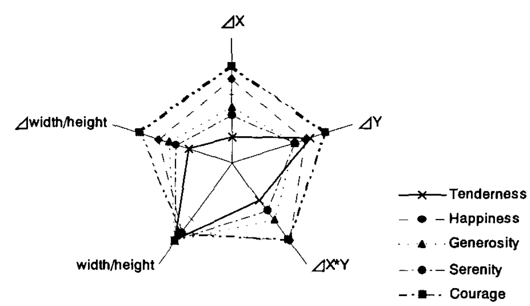


Figure 10. Characteristic of Five dance performances

In the above figure, these five performances would be categorized into three. One is dance of Courage and Happiness. They two have similar feature and higher score than others except for W:H axis. Second particular performance is dance of Tenderness. It has lower than others in a few axes. However, high score along the ΔH line also can be seen. From this, the dance of tenderness are expected to have a characteristic of which the change of height is much often than one of width

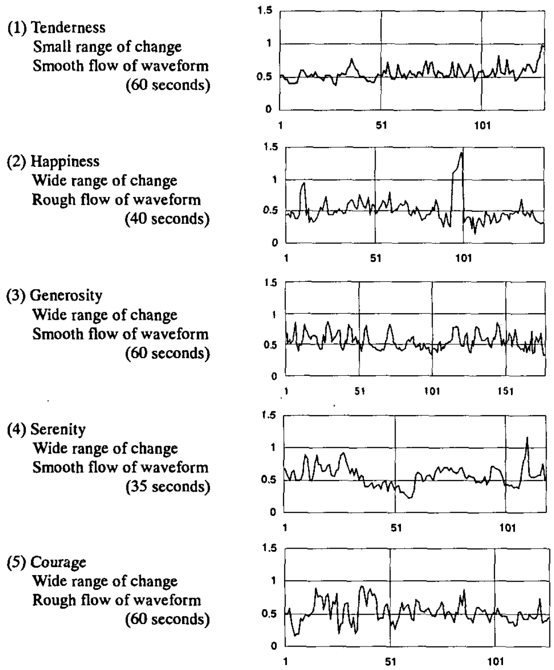


Figure 11. *W:H* waveform of five performances

although the change of size is not so high. Third one is one of Generosity and Serenity.

Another interesting result of analysis is shown in Graph 4. In each graph, x-axis represents the value of *W:H*, while *Y*-axis represents time (second). Comparing to each other, the different pattern of waveform can be read. To better understanding, we introduced two kinds of evaluation with these graphs.

4. CONCLUSIONS AND FUTURE WORK

We have introduced a system to extract symbolic features of human movement. The developed system is a selection of tools attempting to extract KANSEI information directly from basic physical properties of movement (Investigating personal space), and to find a symbolic representation of the qualities of movement suitable for KANSEI analysis. (Investigating general space)

The developed system is able to locate the stretches in space movement is the first important step in classifying movement using Laban's approach. Future work will develop a method to detect the space component of effort while performing a stretch. Very important expressive information can be obtained by the way in which paths are followed in space. A direct movement has got different content from a flexible, round movement performed to reach the same target point.

On the other hand, our work will also go toward the direction of improving the process of direct extraction of KANSEI and developing more effective symbolic descriptions of movement performances following Laban's approach. However, one important point showed by this work is that information is carried not only by the state of a set of observed variables, but by their change in time, so the rhythm of variations during time is and will be a central part of our study.

In the near future this tool will be combined with the system studying the performance in order to better classify the emotional impact of a live performance of dancers. This means that the study of the KANSEI of movement will try to provide a high level description of the dancer performance, modulated by a factor that is function of the spatial position in which the movement is performed.

Recently, we put sensors on some parts of human body (such as limbs, head, and chest) in order to increase input capacity of the investigation of personal space, and this will be reported in the near future. The authors also consider applying the result of analysis to generate emotional movement of human-like robot to dance with humans.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] S. Hashimoto, "On Evaluation and Assessment of Musical Art Technology - Universality and individuality in KANSEI Aspect" *IJCAI'97, Intl. Workshop on AI and Music* (1997)

[2] A. Camurri (Ed.) *KANSEI - The technology of emotion, AIMI International Workshop,* Proceedings. DIST – University of Genoa, Italy (1997)

[3] R. Laban, *Modern Educational Dance*, Macdonald & Evans Ltd., London (1963)

[4] R. Laban and F. C. Lawrence, *Effort*, Macdonald & Evans Ltd., London (1947)

[5] A. Camurri and P. Ferrentino, "Interactive Environments for Music and Multimedia", *Multimedia Systems, Special issue on audio and multimedia,* ACM-Springer (1999).

[6] A. Namekawa, D. Shin, K. Naoi, H. Morita, S. Ohteru, and S. Hashimoto, "On-line Analysis of Pattern of Human Movement and Its Application", Technical Report of IEICE, PRU89-63, pp.37-44 (1989) (in Japanese)

[7] A. Camurri, M. Richetti, and R. Trocca, "EyesWeb – Toward Gesture and Affect Recognition in Dance/Music Interactive Systems". In Proceedings of Int'l conf. of IEEE Multimedia, (1999)

[8] T. Nakata, T. Sato, T. Mori, "Expression of Emotion and Intention by Robot Body Movement" in Proceedings of *International Autonomous Systems 5* (IAS-5), (1998)