Wearable DJ System: a New Motion-Controlled DJ System

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ABSTRACT

The recent reappreciation of music has helped to reestablish the need for the Disk Jockey(DJ), which is someone who selects and plays music. The DJ selects the music, smoothly changes from one song to another, applies sound effects to the music, and this in turn excites the audience. However, conventional DJs cannot get away from the booth because of all the equipment, and thus they are unable to freely perform. Therefore, in this study, we propose a Wearable DJ system that solves this problem that uses wearable computing and gesture recognition technologies. The proposed system enables DJs to perform DJ techniques by performing intuitive gesture operations using wearable acceleration sensors. We have actually used the proposed system on several event stages such as Kobe Luminarie 2007 in Japan. We have evaluated the accuracy of its gesture recognition by changing the parameters and have confirmed its effectiveness.

Categories and Subject Descriptors

H.5.5 [**Information Interfaces and Presentation**]: Sound and Music Computing; J.5 [**Arts and Humanities**]: [Performing arts]; I.5.5 [**Pattern Recognition**]: Implementation—*Interactive systems*

General Terms

Human Factors

Keywords

Disc Jockey Wearable Computing, Motion Recognition

1. INTRODUCTION

Music has become an even more essential part of our daily lives due to the widespread use of a portable audio players such as the iPod by Apple and the Sony Walkman, and there are several online services where users can buy songs anytime and anywhere. A lot of attention recently has been focused on the relationship between humans and Disc Jockey (DJ). Conventionally, people are attracted to music by playing and listening music. However, DJs do play many things such as selecting music, smoothly changing from one song to another, applying special effects to the music that is playing, and exciting the audience. Furthermore, DJs are more creative and provide a more entertaining show with all the progress made in expressive power due to the technological advances in the electrical and electronic fields[1]. However, since current DJs cannot escape from the DJ booth because of their equipment, they cannot freely performance. Moreover, it is difficult for DJs to do physically attractive performances, because conventional DJ equipment use turntables, sliders, and buttons.

Therefore, in this study, we propose a Wearable DJ System that is a new type of motion-controlled DJ system that solves these problems by utilizing wearable computing and gesture recognition technologies. The proposed system enables DJs to perform DJ techniques by using intuitive gesture operations using wearable acceleration sensors. Additionally, DJs can define their own gestures to the system and can assign these gestures to the DJ functions, such as play, cross fading, scratching, and applying effects. Moreover, our proposed system has characteristic functions, which are the gesture restriction function and a gesture recommendation function to reduce the setting costs and to improve the recognition accuracy. We implemented a prototype system and actually used it on several event stages. We confirmed the effectiveness of our system and its functions through evaluation and actual use.

The remainder of this paper is organized as follows. Sec-

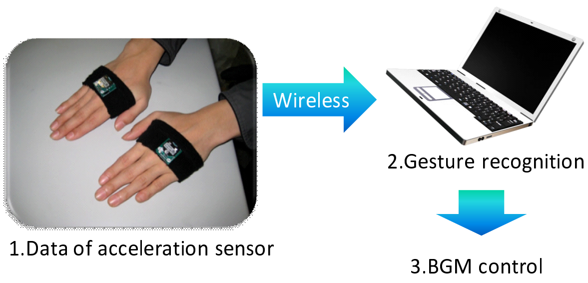


Figure 1: System structure

tion 2 outlines the related work, and Section 3 describes our Wearable DJ System design. Section 4 discusses its implementation and field test. Section 5 explains the improvements made for our system based on actual use. The evaluation results are given in Section 6. Section 7 states the actual use of revised system, and finally, Section 8 presents our conclusions and our planned future studies.

2. RELATED WORK

Advancements have been made in the development of the small sensor device for ensuring a higher level of performance[2]. There are many researches whose goal is to control music control by using both physical and physiological information, such as EMG signals[3], dynamic bending angles of joints[4][5], acceleration[6][7], and image processing[8].

For example, J. Paradiso developed a kind of dance shoe for selecting and playing music using sensors[9]. M. Fujimoto developed a wearable musical instrument that enables dancers to make sounds while b-boying, which is a type of dance style[10]. The purpose of these researches was not to control existing music like with our system, but rather to create music.

T. Fujimoto developed a wearable DJ jacket equipped with a PC and a mobile keyboard[11]. N. Villar developed the ColorDex DJ system using a Cubic Crossfader and an HDDJ device. In addition, portable DJ devices, such as the Hercules mobile DJ[13], Pacemaker[14], and DJammer[15] have been released. Although these devices have enough operationality and portability, they force DJs to perform already decided upon actions. It is difficult to create attractive performances with such a fixed device and buttons that do not have the functions for making things attractive.

3. SYSTEM DESIGN

Conventionally, a DJ performs only in a DJ booth, and it is difficult for audiences to visually understand the techniques performed by a DJ. Therefore, the purpose of our system is to relieve DJs of their placement restrictions by using wearable computing technologies. For this purpose, we propose a Wearable DJ System that makes a DJ's actions visually cool and they give them flexibility. In addition, our system can be used anywhere a DJ wants to perform.

There are four policies for constructing a Wearable DJ System.

1. **No restriction**: a DJ using a Wearable DJ System can perform anywhere, such as a booth, a stage, or the dance floor.

Table 1: List of Wearable DJ functions

Name	Function
Play	Play the music
Stop	Stop the music
Fade-in	A gradual increase in volume of the music
Fade-out	A gradual decrease in volume of the music
Cross fading	Fading one music out while fading another music simultaneously
Volume	Control of the volume
Pan	Control of the balance of L/R channel
Pitch	Control of the pitch of the song
Scratch	Applying the effect like scratch by DJ
Applause	Outputting sound of applause
Effects	Applying the effects to the music
Que point	Play the music from a registered position
Audition	Listening to the next music from another audio line

Table 2: List of effects

Name	Function
Reverberation	To give the persistence of sound in a particular space
Echo	To give effect that is a sound of reflection
Distortion	To distort the sound
Equalizer	Altering the frequency response characteristics of a sound
Compressor	To reduce the dynamic range of an audio signal
Gargle	To add swinging and the shake to the volume
Flanger	To mix the delay sound and produce a swept comb filter effect

2. **Visually recognizable performance**: audiences need to understand what the DJ is doing such as changing the music and applying visual effects. For example, a DJ can increase the volume of the music by raising their hand.

3. **Configuration flexibility**: a DJ should configure the mapping between a gesture and a DJ operation. Moreover, various types of gestures should be accepted by the Wearable DJ System.

4. **Functionality for DJ performance**: Wearable DJ System should have the functions required for common DJ performances such as volume and tempo control, and applying effects.

3.1 System Structure

Figure 1 shows the system structure of the Wearable DJ System. It consists of 3-axis wireless acceleration sensors attached on both hands, and a PC application for processing the acquired sensor data and for controlling back ground music(BGM) based on the mappings between the gestures and DJ functions, which are registered before using the system on stage. Additionally, the Wearable DJ System does not restrict the DJ's actions, because the DJ wears only small sensors on his/her hands. The DJ can move anywhere because they are using wireless communication from the acceleration sensors to the PC. Furthermore, the System enables the DJ to register their own original gestures, and freely customize the recognition level and configure mappings between the gestures and DJ functions for attractive performances.

3.2 BGM Control

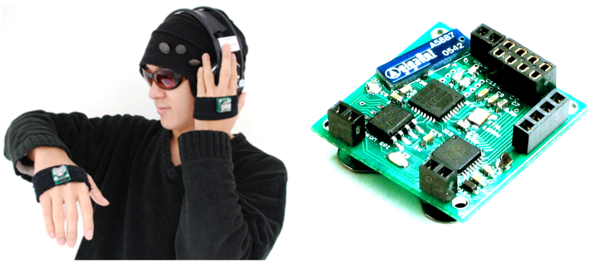


Figure 2: Acceleration sensors on hands

Table 3: Details of device

Communication standard	IEEE 802.15.4
Communication speed	250kbps
Communication bandwidth	2.4GHz
The number of channels	16ch
Communication distance	75m
Micro computer chip	AVR ATMega 168 8MHz
Interface	USART $\sim$ 115kbps
	SPI 8Mbps
	Analog/Digital I/O $\times 8$
Power source	DC3.3V
	CR2032 Button cell
A consumption electric current	Active: 30mA
	Sleep: $10\mu A$

Table 1 lists the BGM control functions of the Wearable DJ System, and Table 2 lists the details of the effect functions. The Wearable DJ System has the functions for not only playing and stopping music but also for fade-in, fade-out, and cross fading in order to smoothly change the music. Moreover, the System has functions to control the volume, pan, and pitch, and to scratch and use effects. A DJ listens to the next music to play through headphones to check the song and its pitch information to smoothly change the music.

3.3 Gesture Recognition

All the functions in Wearable DJ System can be controlled by gestures. A user wears 3-axis wireless acceleration sensors on both hands, as shown in Figure 2. The size of sensor is 25(D) $\times$ 25(W) $\times$ 9.5(H) mm and each weighs 4 g without a battery[16]. The details for this device are listed in Table 3. The wearable sensors continuously transmit motion data to the PC application via wireless communication. The system recognizes a gesture by comparing the acquired gesture with the stored gesture data from the gesture database.

We considered two recognition methods, a method using instantaneous acceleration data and a method using time series acceleration data. The former method enables the system to control the BGM in real time, because the system is able to directly convert the acceleration data into BGM control information, but this method has a limited number of control patterns. On the other hand, the latter method has difficulty reflecting the result to the BGM control in real time, because there are various kinds of gesture patterns. Note that the Wearable DJ system uses a dynamic programming (DP) matching algorithm to analyze the time series acceleration data[17]. DP matching is a well-known method for retrieving the similarities in time series data such as speech or motions.

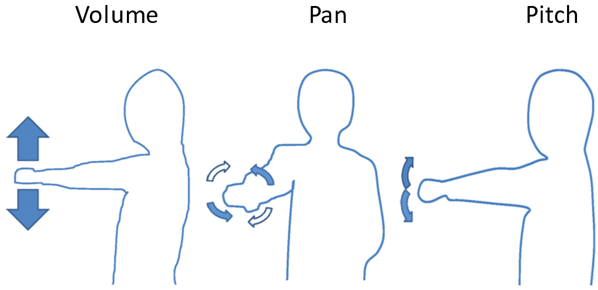


Figure 3: Control of volume, pan, and pitch

Figure 4: Snapshot in Kobe Luminarie

We selectively use both methods by taking the characteristics of the functions into consideration, because both methods have advantages and disadvantages. Our prototype system continuously controls the volume, pan, and pitch during a DJ performance, so that these controls are suited for a method using instantaneous acceleration data. Figure 3 shows the control methods for the volume, pan, and pitch in the initial prototype. The volume is controlled by raising and lowering the hand and the pan is controlled by twisting the wrist. A clockwise/counterclockwise turn is associated to the degree of R/L channel. The pitch is controlled by raising or down lowering wrist. When raising or lowering the wrist, the pitch gets higher/lower.

On the other hand, other functions, such as play, stop, and scratch, are operated by gestures.

Since the use of current acceleration data for controlling the system functions creates unintended controls, we have prepared gestures to enter/exit the mode to control the volume, pan, and pitch, to stabilize the controls.

4. IMPLEMENTATION & PERFORMANCE

As described in Section 3.1, we need small wireless 3-dimensional acceleration sensors that can be worn on on hands. Since no suitable sensors were available commercially, our research group developed a new wireless sensor module named the “Nao-RF Chip”. We implemented a pro-

Table 4: Example of confusion matrix

Threshold	Gesture	1	2	3	4	5	false negative
30	1	7	0	1	0	2	0
30	2	1	8	0	0	0	1
30	3	2	0	6	2	0	0
30	4	0	0	2	8	0	0
30	5	2	0	0	0	7	1

Threshold	Gesture	1	2	3	4	5	false negative
40	1	10	0	0	0	0	0
25	2	1	9	0	0	0	0
40	3	1	1	7	0	0	1
35	4	0	0	0	9	0	1
30	5	0	0	0	0	9	1

totype system on Windows XP using Microsoft Visual C# .NET 2005 and DirectSound library of Direct X.

We have used the prototype on an actual event stage at the Kobe Luminarie Live Stage on December 8th and 9th, 2007, as shown in Figure 4[18]. Kobe Luminarie is a light festival held in Kobe, Japan every December. It began in 1995 and commemorates the Great Hanshin earthquake that happened that same year. The first author performed using the Wearable DJ System on this stage. In the show, various types of functions were used such as play, fade-out, cross fading, the sound effects of the applause to heat up the floor, and adjustments were made in the volume, pitch, pan, and applying effects.

It is easy for the audience to understand a performer's operations because of the allocation of intuitive gestures to the DJ functions. Additionally, we assigned showy gestures for playing and stopping the music. When these gestures were made at appropriate times on the stage, shouts of applause came from the audience.

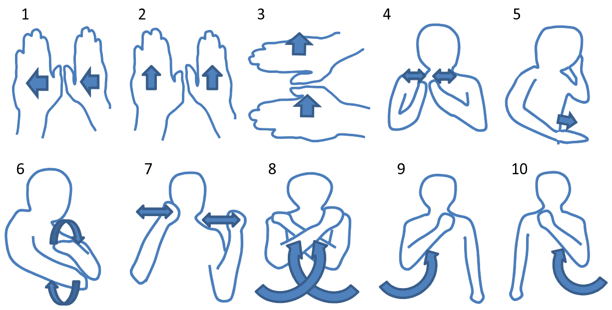
On the other hand, the system has been freezing because of instability in the wireless acceleration sensors, and there were mis/non-recognitions on the stage. These are critical problems and must be settled. Moreover, the DJ had difficulty freely move on the stage, because the training gestures sets had been gathered while standing still and flexible movement might decrease the accuracy of the gesture recognition. As for the assignment between the functions and gestures, it was difficult and cumbersome for the user to extract the most suitable combination because there were a lot of combination candidates and consideration points, such as recognition ratios/false positives/false negatives.

5. IMPROVEMENT

We found several problems from the results of the pilot test as described in the previous section. To solve these problems, we propose a gesture restriction and a gesture recommendation function.

5.1 Gesture restriction function

The Wearable DJ System enables a DJ to move anywhere they wish. However, if the DJ changes his/her stance such as standing, moving, and sitting down, the accuracy of the gesture recognition worsens because such motions peculiar to each situation strongly effect the acquired motion data



Gesture1 Both hands move in direction of x positive axis
Gesture2 Both hands move in direction of y positive axis
Gesture3 Both hands move in direction of z positive axis
Gesture4 Applause
Gesture5 Scratch
Gesture6 Both hands are turned in front of the body
Gesture7 Both hands are shaken right and left
Gesture8 Both hands are intersected in front of the body
Gesture9 Only the right hand is raised
Gesture10 Only the left hand is raised

Figure 5: Gestures used in evaluations

from the sensors and this prevents the system from correctly recognizing gestures. To solve this problem, we use an additional acceleration sensor attached on the DJ's thigh to detect their stance. In the pilot system, all the gestures were available for all situations, but this gesture restriction function enables the system to change a set of available functions according the given situation. This means that the gesture candidates to be recognized are narrowed down and the recognition accuracy improves.

The following an example of the setting used in the revised prototype system.

1. All functions are inactivated in the case of "moving".
2. The play and stop functions are activated for "standing" and "sitting down".
3. The volume, pan, and pitch controls are also activated for "standing" and " sitting down". In addition, the volume, pan, and pitch resolutions for "sitting down" is different from that of "standing" for finely controlling them.
4. Applause, scratching, and effects are activated for only "standing".

5.2 Gesture recommendation tool

To use our system, a user must associate the gestures to DJ functions. In the pilot system, it was difficult for a DJ to do this procedure because there is no hint or recommendation for the association between functions and gestures. Each gesture has its own characteristics explained as several parameters, such as the recognition accuracy, the false positive ratio, and the false negative ratio. In particular, there is the possibility that two specific gestures get confused. The DJ must consider these parameters carefully to decide the association between the gestures and the DJ functions. This is because the quality of the performances deeply depends

Table 5: Recognition ratio for each threshold

Threshold	Gesture number									
	1	2	3	4	5	6	7	8	9	10
10	83	0	100	13	0	100	0	13	0	50
	17	100	0	0	100	0	100	87	100	50
	0	0	0	87	0	0	0	0	0	0
20	100	100	100	90	20	100	23	93	93	100
	0	0	0	10	80	0	73	7	7	0
	0	0	0	0	0	0	3	0	0	0
30	100	100	100	100	77	100	87	100	100	100
	0	0	0	0	13	0	0	0	0	0
	0	0	0	0	10	0	13	0	0	0
40	77	77	100	53	50	87	40	100	100	97
	0	0	0	0	0	0	0	0	0	0
	23	23	0	47	50	13	60	0	0	3
50	30	23	100	0	13	10	0	100	90	80
	0	0	0	0	0	0	0	0	0	0
	70	77	0	100	87	67	100	0	10	20

on such parameters. For example, usually a DJ thinks that the critical functions such as playing music and stopping music should be associated with the gestures that are accurate enough and have a low false positive ratio. In addition, both the playing music function and stopping music function must not be recognized as a single action. On the other hand, there is a case where the reverberation function should be assigned to the gestures that have low false negative ratios even if they have high false positive ratios. In this way, each DJ function has a restriction on such parameters and it is difficult to decide what the optimal assignment is between the functions and gestures. Moreover, such parameters drastically change according to the DP matching threshold .

Therefore, we propose a gesture recommendation tool by using a confusion matrix that includes information on the correct-recognition ratio, false negative ratio, false positive ratio and its distribution. To use this tool, the user sets the requirements for each DJ function on a minimum recognition ratio, a maximum false positive ratio, a maximum false negative ratio, and a maximum identification error ratio to each specific function. The system automatically calculates the confusion matrix for all thresholds patterns, and extracts the most suitable combination between the DJ functions and gestures with a set of optimal thresholds for the gestures. We show an example of a recommendation by using the sample confusion matrixes listed in Table 4. Two cases of threshold settings are shown in the table; the upper matrix and bottom matrix (note that the system calculates a large number of patterns in the threshold settings in actual situation). In the table, Threshold represents the recognition threshold for each gesture, and gesture refers to the gesture ID and each number in the first line represents the gesture ID to which the correct gesture is mis-recognized. False negative represents the number of false negatives. In this situation, we assume that a user has defined the recognition accuracy of a gesture for the scratch function to be over 95%, the false negative ratio and false positive ratio of the gesture for applause to be under 15%, and the gestures for the music play function and music stop function not to be mis-recognized. When taking such requirements into account, the system recommended the following combinations between gestures and functions; with the bottom thresholds, Gesture 1 was a scratch, Gesture 2 was applause, Gestures 4 and 5 were music play and music stop, respectively, because this setting completely met the requirements.

Table 6: Allocation of gestures

Function	Gesture	Threshold
Play first song	1	30
Play second song	2	30
Play third song	3	50
Stop first song	6	40
Stop third song	8	50
Volume change ON	9	50
Volume change OFF	10	50
Applause	4	40
Scratch	5	35
Effect	7	30

6. EVALUATION

6.1 Influence of threshold

We conducted an evaluation to investigate the recognition ratio when changing the threshold of DP matching for ten kinds of gestures shown in Figure 5. The lower the threshold is, the easier the system recognizes the gesture even if the gesture is different from the training data. Threshold “100” means there was complete matching between the gesture training data and the presented gesture. We changed thresholds “10”, “20”, “30”, “40”, and “50”, because it is rare for the gestures to completely match. Each gesture was performed 30 times.

Table 5 lists a result of the recognition ratio. The first line in the results for each threshold shows the correct-recognition ratio, and the second line shows the false positive ratio while the third line shows the false negative ratio. In whole, the higher the threshold value is, the more the false negative ratio increases and the false positive ratio decreases. The correct-recognition ratio is comparatively high for simple gestures such as gestures 1, 2, 3, 6, and 8. Gesture 4, which is simple but has a motion impact shock, and Gesture 5, which is a complicated movement, are not recognized under the high threshold. The system did not recognize the gesture where the examinee twisted his wrists for Gesture 7. Gesture 7 is not easy to recognize under the high threshold.

Table 8: Combination of situation and gesture

Gesture	Sitting	Standing	Moving
1	○	○	×
2	○	○	×
3	○	○	×
4	×	○	×
5	×	○	×
6	○	○	×
7	×	○	×
8	○	○	×
9	○	○	×
10	○	○	×

According to these result, the most appropriate thresholds vary according to gestures.

6.2 Adaptive threshold

The most appropriate threshold for each gesture is acquired from Table 5. We investigated the recognition ratio in the following scenario, which were assumed from the actual use of the system on stage.

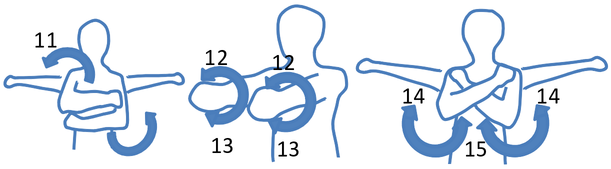
1. Playing the first song.
2. Volume control for the first song.
3. Stop of the first song.
4. Playing sound of applause.
5. Playing the second song.
6. Volume control for the second song.
7. Cross fading between the second and third songs.
8. Volume control for the third song.
9. Making five scratching sounds.
10. Applying Reverberation effects.
11. Stopping the third song.

The gestures for these items are listed in Table 6. The gesture numbers shown in Table 6 correspond to those in Figure 5. The value for each threshold listed in Table 6 was set according to the user's requirements and the results in the previous section. The examinee performed this scenario 30 times. We compared the recognition ratio of this case with that with the fixed threshold, which was 30.

The mean recognition ratio of the fixed value was 65%, while that of the adaptive threshold was 88%. The more detailed results are listed in Table 7. The false positive ratio of gesture 4 decreases when the threshold is used. In addition, though there are multiple reactions in one movement for gestures 9 and 10, this problem is solved by using a higher threshold.

Table 9: Recognition ratio when applying gesture restriction function

Gesture number									
1	2	3	4	5	6	7	8	9	10
97	100	100	60	93	100	97	90	58	61
0	0	0	33	0	0	0	0	38	33
3	0	0	7	7	0	3	10	4	6



Gesture11 Both hands are turned and opened
Gesture12 Both hands are turned clockwise
Gesture13 Both hands are turned counterclockwise
Gesture14 Both intersected hands are opened
Gesture15 Both opened hands are intersected

Figure 6: Gestures used in evaluations

6.3 Gesture restriction function

We conducted an evaluation to investigate the effectiveness of the gesture restrictions function. We examined the recognition ratio when using the gesture restriction, with the fixed value of threshold 30, and using the same performance scenario as used in the previous evaluation. Table 8 lists the combinations of situations and gesture restrictions. "○" in Table 8 designates that the gesture can be used in the situation.

Comparing the result listed in Table 9 with the fixed threshold given in Table 7, although the recognition ratio for Gestures 9 and 10 are almost same, the false positive ratio of Gesture 4 and the false negative ratio of Gesture 5 improve. Moreover, comparing these results with the results for the adaptive threshold in Table 7, we found that the false negative ratio of Gesture 5 improves. However, the correct-recognition ratio of Gestures 9, and 10 worsen.

Furthermore, we confirmed that the correct-recognition ratio increases to 94% when both this function and the adaptive threshold are used together.

As a result, we confirmed the effectiveness of the gesture restriction function.

6.4 Gesture recommendation function

We evaluated the effectiveness of the gesture recommendation function under almost the same conditions as those described in Section 6-B. Moreover, we added the five new kinds of gestures in Figure 6 to the gestures shown in Figure 5 because the system needs a certain number of alternative gestures to recommend suitable combinations. Additionally, we assumed the gestures for "Play of a third song", "Stop of a third song", "Volume control off", "Scratch", and "Applause" were allocated to the same gestures listed in Table 6. The others were assigned as listed in Table 10 by using the gesture recommendation function. The requirements used in this evaluation were that the combinations get 1∼10 points

Table 7: Recognition ratio - fixed threshold v.s. adaptive threshold

	Gesture number									
	1	2	3	4	5	6	7	8	9	10
	100	90	100	37	85	100	83	97	63	70
Fixed	0	0	0	60	0	0	0	0	37	30
	0	10	0	3	15	0	17	3	0	0
	30	93	93	83	68	93	77	97	100	100
Adaptation	0	0	0	0	0	0	0	0	0	0
	0	7	7	17	32	17	23	3	0	0

Table 10: Allocation of gestures

Function	Gesture	Threshold
Play first song	1	30
play second song	2	30
Play third song	3	40
Stop first song	6	35
Stop third song	8	40
Volume change ON	15	40
Volume change OFF	10	50
Applause	4	35
Scratch	5	30
Effect	13	30

Table 11: Recognition ratio when using gesture recommendation tool

Gesture number									
1	2	3	4	5	6	13	8	15	10
100	87	93	67	93	93	100	100	100	100
0	0	0	7	0	0	0	0	0	0
0	13	7	6	7	7	0	0	0	0

each when a correct-recognition of a function is 85∼95% or over, get 5∼15 points when the false negative ratio of each function is 3∼10% or under, and get 10 points when the false positive of each function is 10% or under. We evaluated the recognition ratio with recommended combinations between gestures and functions. The results listed in Table 11 are almost the same when using the adaptive threshold. While the false positive ratio of applause (result of Gesture 4 in Table 11) worsened. On the other hand, the correct-recognition ratio of scratch (result of Gesture 5 in Table 11) improved, because the gesture recommendation function enables the correct-recognition ratio to be considered over the other gestures. Additionally, requests such as "Stop needs to be assigned to the gesture that is a lower false positive", "It prevents both play and stop from being activated at the same time in one action" are satisfied.

As a result of this evaluation, the effectiveness of the gesture recommendation function is proved.

7. ACTUAL USE BY A PROFESSIONAL DJ

The Wearable DJ System was actually used by a professional DJ at a nightclub on February 23th, 2009. The DJ operated various DJ functions such as play, cross fading, adjustment of volume, pan, and pitch using the Wearable DJ System at the event as shown in Figure 7. We received the following comments from the DJ after using it. Additionally, the DJ evaluated the system by ranking (1: worst, 5: best). The questions and scores are listed in Table 12.

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Figure 7: Professional DJ using Wearable DJ System

Table 12: Result of the questionnaires

Item	Evaluation
Cool	5
Interest	5
Satisfied with function	4
Recognition accuracy	3
Recognition speed	3
Plainly of synchronization	5

1. The Wearable DJ System was cool and were effective for the performance.
2. It was easy for me to use the system.
3. The audiences were more excited while using the system.
4. I want to use the system at the next event.
5. The DJ functions were adequate for the performance, but I want to use more various kinds of effects.
6. I felt there was some delay between performing a gesture and the sound changing.

From these comments, we confirmed the Wearable DJ System is effective as a new tool for DJs. However, we have some problems in regard to the recognition ratio and the recognition speed.

8. CONCLUSION

We have proposed and implemented the Wearable DJ System to control the BGM through motion acquired through acceleration sensors. The Wearable DJ System enables the DJ to move freely and to perform creative and cool DJ operations by using motion recognition techniques that use DP matching. Additionally, we have proposed the gesture restriction function and the gesture recommendation tool to reduce the setting time and to improve the recognition accuracy. The results of the evaluation and field tests confirmed that the Wearable DJ System was effective in DJ performances.

In the future, we plan to propose a script language and a GUI that enables a user to more easily allocate between a gesture and a DJ function, and to enhance the power of the movement expression by using new kinds of sensors.

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