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Image Training Assist System for Motor Skill Learning

Katsunori Ishii, Junichi Hatayama, Kazuhiko Seki, Tomohiro Kobayashi, Hideki Murakoshi, and Hiroshi Hashimoto.

Abstract-In this paper, we propose image training assist system for motor skill learning. The system consists of a monitor, cameras, sensors, and PCs. The system captures the learner's motion and displays the learner's motion by 3D graphics in the virtual environment on the monitor. The learner can put down a point and comments in the virtual environment displayed by the monitor. Since the point is overlapped on the instructor's motion and displayed while learning, the learner can train the motor skill with the specified point. Moreover, the system provides effective functions for the motor skill learning such as the comparison between the learner's motion and the instructor's, the current and the past. We adapt the system to learning Kyudo (Japanese traditional archery) as one of the motor skill learning, and evaluate the image training assist system.

I. INTRODUCTION

By the development of computer networks and multimedia technology, the e-Learning system that we can learn at favorite place in any time is studied flourishingly. The e-Learning systems are studied not only for a lecture but also for the motor skill learning, and they are attracted attention. The e-Learning system with multimedia interface is expected for supplying non-verbal information such as motor skill learning. However, the e-Learning systems for the motor skill learning at present provide only one-way guidance to the learner [1] [2]. And it is difficult to say that they provide effective learning environment for the motor skill learning.

When we learn the motor skill, we cannot acquire the motor skill by knowing only the form and the action timing as the external information of a body. We acquire the motor skill by accumulating knowledge that we repeat learning the motion image and the proprioceptive sense [3] [4] (In this paper, we call the motion image and the proprioceptive sense the motor sense). It is not able to transfer the motor sense directly, because the motor sense is internal information in his/her mind and different from each other. However, the learner individually recognizes the motor senses. Then we propose the image training assist system that promotes accumulating the motor sense and acquiring the motor skill. The learner can records and retrieve the motor sense by using the image training assist system. We implement the image training assist system and apply to Kyudo (Japanese archery) as one of the motor skill learning for evaluation. We show the system is effective for motor skill learning by experimental results.

The motor sense for the motor skill learning is explained in section II. The system configuration is explained in section. The compare function for the motion skill learning is explained in section IV. The procedure of the motor skill learning is explained in section V. Application of the system to Kyudo is explained in section VI. Experiment is explained in section VII. And section VIII is the conclusions of this paper.

Kazuhiko Seki is with Tokyo Metropolitan Institute of Technology Department of Electronic System Engineering, 6-6, Asahigaoka, Hino City, Japan 191-0065(e- mail: seki@ml.ec.tmit.ac.jp)
Junichi Hatayama is with Tokyo Metropolitan Institute of Technology Department of Electronic System Engineering, 6-6, Asahigaoka, Hino City, Japan 191-0065(e- mail: jun-1@ml.ec.tmit.ac.jp)
Katsunori Ishii is with Tokyo Metropolitan Institute of Technology Department of Electronic System Engineering, 6-6, Asahigaoka, Hino City, Japan 191-0065(e- mail: ishii@ml.ec.tmit.ac.jp)
Tomohiro Kobayashi is with Tokyo Metropolitan Institute of Technology Department of Electronic System Engineering, 6-6, Asahigaoka, Hino City, Japan 191-0065(e- mail: ruche@ml.ec.tmit.ac.jp)
Hideki Murakoshi is with Tokyo Metropolitan Institute of Technology Department of Electronic System Engineering, 6-6, Asahigaoka, Hino City, Japan 191-0065(e- mail: hm@tmit.ac.jp)
Hiroshi Hashimoto is with Tokyo University of Technology, 1404-1,Katakura town, Hachioji City, Tokyo, JAPAN 192-0982(e- mail: hasimoto@cc.teu.ac.jp)

II. THE MOTOR SENSE FOR THE MOTOR SKILL LEARNING

(A) The needed function for the process of the motor sense learning

1) A learning process when we learn the motor skill is as follows.
2) A learner imagines a motion to aim in his/her head.
3) The learner trains the motor skill, and recognizes a proprioceptive sense in his/her motion.
4) The learner recognizes a result of his/her motion after he/she trains. And, the learner recognizes a difference of learner's motion and the motion image that learner aim.
5) The learner compares the motion that he/she performs at present with the motion that he/she performs until now. The learner compares motor senses in same way.
6) The learner recognizes a tendency of his/her motion.
7) The learner draws a new motion image in his/her head with them.
8) The process is repeated from 2) to 7).

Like this, the learner acquires the motor skill not only repeating merely the motion but also analyzing the patterns that are easy to mistake the motion based on experience. However, it is difficult to remember precisely the motor sense and results of trial that learner repeated several times. And, it is very difficult that the learner acquires a tendency of the motor in the same way.

We implement a function to manage information of learner's motion and internal information of the motor sense in the system. The function manages the information that is related to the motion and results of the motion and the motor sense. The result of the motion is evaluation result to learner's motion by the evaluation system. The system evaluates learner's motion by comparing coordinates of learner with coordinates of the sample motion that we measured beforehand. The learner can choice the motions as a standard at the evaluation score in motion history, and can look the past motion. The learner can research recorded information of the motor sense by recording function of the motor sense and look them. The learner can self-analyze effectively so that the learner can compare the motor sense with the past motion by the function. The learner can record a new motion image as information of the motor sense in a learning process 5). The learner can feed back the information that he/she recorded by a sight effect in next trail. By this, the learner can reduce timing gap of the motion image and the motion.

(B) The method of recording the motor sense

We can divide the motor sense between a motion images and that a learner gets into the proprioceptive sense while the motor skill learning. When a human moves each parts of his/her body and they are moved, the proprioceptive sense is an organ taking in internal stimulation such as the direction and a quantity. In short, it is the sense to show whether each part of body moves. The motion image is description how the learner performs the motion that he/she aims and imagine in his/her head before performs. It is the proprioceptive sense that the learner turns consciousness for parts of learner's body in same way. Therefore, an object that the learner records the motor sense is each part of the learner's body. We have to put down a point at an arbitrary object in any time while the motor skill learning. We suggest the system to be able to recode them intuitively.

Sensors capture a learner's motion. The learner's avatar is displayed in the virtual environment on a monitor by 3D graphics. The learner can put down points for the learner's avatar at an arbitrary place in any time, and clicking a point that the learner want to put down with a mouse as two circles to show in A of figure 1. At first, 2 dimensional points that the learner clicked is converted 3 dimensional points by the function. In detail, the system converts 3 dimensional vectors by a projection matrix, a viewpoint of a camera, and a direction of 3 dimensional coordinates. The system computed a vector that going from clicked point to avatar. A point is an intersectional point of the vector and avatar. And, the learner can record the motion image. Moreover, the learner can record detail information for the point. In short, the learner puts down comments with a keyboard to show it in B of figure 1.

The system can record the motor sense by putting down the points and the comments with a mouse and a keyboard for learner's avatar.

Figure 1.Recording the motor sense

(C) Method of calculating three dimensional coordinates from two dimensional coordinates

Figure 2 is the space area where the camera is seen on the virtual environment. Six planes compose this area.

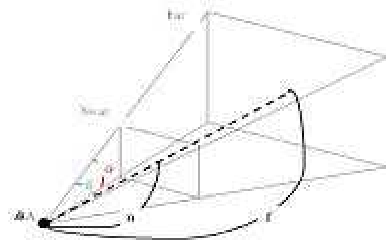

Figure2. The space area where the camera is seen

The plane with point A forward is called near clip plane. The plane in the interior of point A is called far clip plane. Point A is a position of the aspect of the camera. The distance from this aspect to the near clip plane is defined as n. The distance from this aspect to the far clip plane is defined as f. The angle in the vertical direction of the camera in point A is defined as α. The angle in the horizontal direction of the camera in point A is defined as β. These values are used to generate the projection matrix and the view matrix. The projection matrix is a matrix that decides the position in which the object on the virtual environment draws on the two dimensional plane. The view matrix is a matrix with information on the viewing angle of the camera and the direction. When the position of the object in the virtual environment is defined e, and the point in two-dimensional planes is defined r, the matrix is requested by the next formula (1)(2)(3). Three dimension coordinates are calculated by doing the operation opposite to conversion from three dimension coordinates to two dimension coordinates. When the mouse is clicked, this is conversion of the position on the near clip plane on the virtual environment. The position of vNear and vFar is place between back and forth of avatar in view of the camera. The vector that faces avatar from vNear is defined as vDir. The position that this vDir collided with avatar becomes a marking point.

$$persMat = \begin{pmatrix} \frac{1}{a \cdot \tan(\beta/2)} & 0 & 0 & 0 \\ 0 & \frac{1}{\tan(\beta/2)} & 0 & 0 \\ 0 & 0 & \frac{f}{f-n} & 1 \\ 0 & 0 & -\frac{f \cdot n}{f-n} & 0 \end{pmatrix}$$

$$viewMat = \begin{pmatrix} xaxisx & yaxisx & zaxisx & 0 \\ xaxisy & yaxisy & zaxisy & 0 \\ xaxisz & yaxisz & zaxisz & 0 \\ -dot(xaxis, eye) & -dot(yaxis, eye) & -dot(zaxis, eye) & 1 \end{pmatrix}$$

(1)

$$\begin{bmatrix} x2 \\ y2 \\ z2 \\ w2 \end{bmatrix} = \begin{bmatrix} x3 \\ y3 \\ z3 \\ w3 \end{bmatrix} \cdot worldMat \cdot persMat \cdot viewMat \quad (2)$$

$$\begin{bmatrix} sx \\ sy \end{bmatrix} = \begin{bmatrix} \frac{Width(x2/w2+1)}{2} \\ \frac{Height(y2/w2+1)}{2} \end{bmatrix} \quad (3)$$

$$vDir = vFar - vNear \quad (4)$$

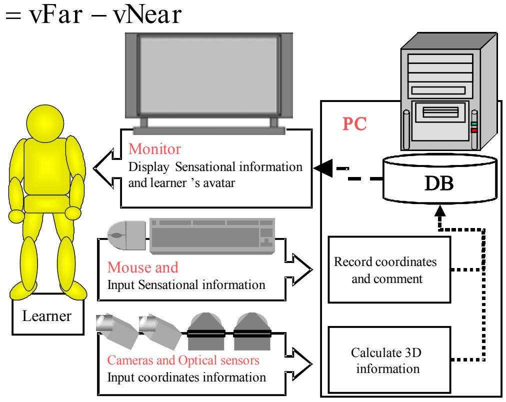

Figure3.System configuration

III. SYSTEM CONFIGURATION

The system consists of a monitor, cameras, sensors, a mouse, a keyboard, and PCs. A learner learns motor skill while looking instruction information displayed on a monitor. The system captures learner's motion with USB cameras, optical sensors, and an ultrasonic sensor, when the motor skill learning. At first, we explain the USB cameras capture learner's motion. The captured picture is sent to program in a PC. The program can detect coordinate of arbitrary objects from the color-feature on the captured picture. Next, coordinates of detecting points are computed from optical sensors, an ultrasonic sensor, and pictures by USB cameras. The coordinates display the learner's avatar as 3D graphics in virtual environment on a monitor. The learner records information of the motor sense with a mouse and a keyboard while looking the motion of learner's avatar. Recorded information of the motor sense and the coordinates are stored a database in a PC. When the learner refers to the motion history and history of the motor sense, they are researched and looked, and they are displayed on a monitor.

IV. COMPARISION FUNCTION FOR THE MOTOR SKILL LEARNING

(A) A function to compare the motion images with the motions

When a learner trains the motor skill, it is very difficult to judge the difference between the learner's motion and the motion image that the learner aim. The reason is because the motion image is imagined in the learner's head and is not actual motion. Comparing the motion image with the actual motion is vague, and it is very difficult to judge an error of the action timing for the motion. Therefore, the learner has to be able to judge a difference between the actual motion and the motion image that the learner imagines in his/her head.

When training the next trial, the modifying information that he/her recorded is overlapped a sample motion, and they are displayed. The learner can recall the modifying information that he/she recorded while the motor skill learning, and can reduce an action timing gap of the motion image and the actual motion.

(B) A function to compare motions

A learner can refer to the motion and the motor sense that he/she recorded for learner's motion. Moreover, a learner choices two motions in motion history and can look them simultaneously. By looking them, the learners can self-analyze difference of motions by the gap of the time that felt a proprioceptive signal. When the learner choices in the motion history, the learner can choice two motions based on the evaluation score that is evaluated by the evaluation system. By this, the learner can compare differences of the motor senses.

V. PROCEDURE OF THE MOTOR SKILL LEARNING

A learner logs in after the system start. If it is the first use for the learner, at first the learner learns the current of the motion. After learning the motion, the learner recognizes the motion result that the learner performed at present, and he/she record what ha/she felt in motor skill learning (the proprioceptive sense) and what ha/she was conscious of (the motion image). The system uses recording function of the motor sense for recording them. (We call recorded the information sense information.)The learner thinks a new motion image from any information (the proprioceptive sense, the motion image, the motion result) that he/she got by the motion at present. The learner records them by recording function of the motor sense same as the sense information. (We call the information the modifying information.) The learner can look the modifying information as the feedback information in the next motor skill learning trial with training the motor skill. We call the function that can look the feedback information "A function to compare the motion images with the motions". When the learner looks in the motion history, he/she can compare the motor senses that he/she recorded by choosing two motions in the motion history, and can compare his/her motions in same way.

VI. APPLICATION TO THE SYSTM OF KYUDO

We adapt the system to learning Kyudo (Japanese traditional archery) as one of the motor skill learning for evaluation. Kyudo is sports for the purpose of what shoot arrows and hit a target. However, Kyudo is very important to the process of the motion before hitting a target. The process of the motion is more important than hitting a target in a promotion examination of Kyudo. The process of the motion to shoot one arrow in Kyudo is called Shahou-Hassetu, and consists of eight elements. The eight elements are Ashibumi, Douzukuri, Yugamae, Utiokoshi, Hikiwake, Kai, Hanare, and Zanshin. Shahou-Hassetu is illustrated in Figure4.

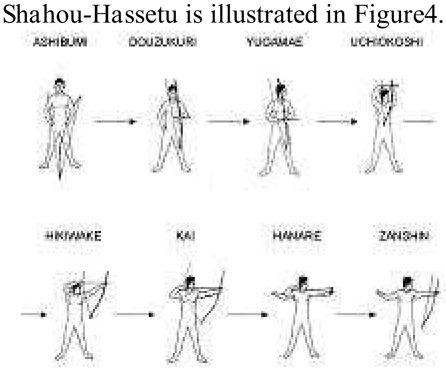

Figure4. Shahou-Hassetu

Stillness and movements are repeated in the Shahou-Hassetu. Fixed time is decided in each element. A learner must repeat stillness in fixed time and movements in fixed time. For example, the learner moves in fixed time in Hikiwake, stands still in fixed time in the next of Kai. Moreover, it is assumed that the motions are good so as not to sway when the learner stands still. In this way, the motions are strictly decided in Kyudo. The learner takes a learning form to modify the motion that is only one [5] [6].

1) A learning environment is not different every one trial. Therefore, the system is easy to understand a learner's improvement.
2) A learner has consciousness of only his/her motion. In other word, there is a little sense of incongruity when a learner used what he/she didn't use until now such as recoding function for the motor sense.

The learning object of Kyudo is the reason why Kyudo is such sports.

An evaluation system is necessary in order to get a motion result. The evaluation system to learning Kyudo evaluates Goju-Jumonji and Sanju-Jumonji that are used as evaluation of form by Kyudo instructor. In addition, the evaluation system evaluates action timing. (A) Evaluation system configuration

Figure5 is shown the evaluation system configuration for Kyudo. A learner trains Kyudo with looking the instruction motion (form, and action timing) displayed in virtual environment on a monitor. The evaluation system captures learner's motion with USB cameras, optical sensors, and an ultrasonic sensor, when the learner trains Kyudo. The USB cameras capture learner's motion. The captured picture is sent to program in a PC. The program can detect coordinate of arbitrary objects from the color-feature on the captured picture. The system computes 3 dimensional coordinates by DLT method [7]. Coordinates of detecting points are computed from optical sensors and USB cameras. The coordinates display a learner's avatar displayed in virtual environment on the monitor. Coordinates information are stored to a database, and evaluate learner's motion from the coordinates information. After his/her motion was evaluated, the system stores the learner's motion and an evaluation result of the learner's motion with a database.

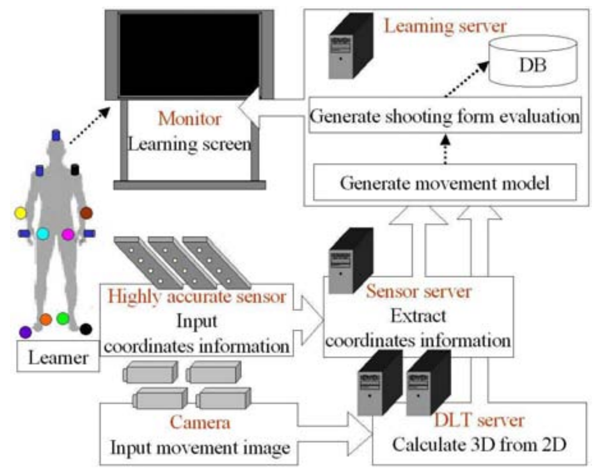

Figure5.System configuration

(B) Method of measuring learner's motion

The evaluation system acquires coordinates of points to evaluate as important points. Important learning elements of Kyudo are Goju-Jumonji and Sanju-Jumonji, action timing in each element.

(a) Method of measuring two Jumonji

Sanju-Jumonji is a basic form to shoot one arrow. Sanju-Jumonji is illustrated in Figure6. Sanju-Jumonji is three crosses. There are a straight line of both legs (A) and a straight line of waists (B) and a straight line of both shoulders (C). Three straight lines have to be parallel and the same plane. Sanju-Jumonji is three points to cross three straight lines and a straight line of the center of body (D). And, It is called Sanju-Jumonji is formed, when it is the state that the three crosses becomes perpendicular. Sanju-Jumonji must become perpendicular in all elements. Therefore, Sanju-Jumonji is the most important when training Kyudo.

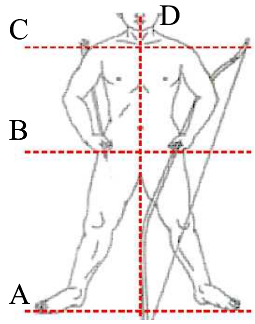

Figure6.Positions of Sanju-Jumonji

Goju-Jumonji is a basic form to shoot one arrow, too. Goju-Jumonji is illustrated in Figure7. Goju-Jumonji is five crosses. There are a scruff and an arrow (F and I), a bow and an arrow (G and H), the left hand (G and H), a thumb of the right hand and a string (E and H), the middle of a body and shoulders (F and H). Goju-Jumonji is five points to cross six straight lines. And, It is called Goju-Jumonji is formed, when it is the state that the five straight line becomes perpendicular. A fivefold cross must be formed while Yugamae, Utiokosi, Hikiwake, and Kai.

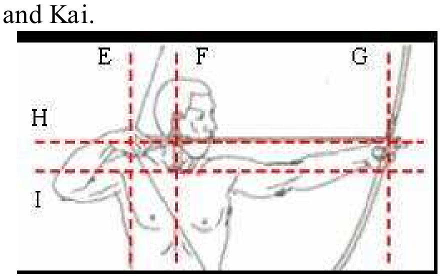

Figure7.Postions of Goju-Jumonji

An evaluation system evaluates angles of intersectional points of six straight lines of Goju-Jumonji and four straight lines of Sanju-Jumonji and the positions in each element of Shahou-Hassetu. We detect the positions and angles of intersectional points. Therefore measurement coordinate point is waists, heels, and tiptoes of legs, a head, shoulders, and elbows, shell of hands. The detecting points are illustrated in figure7. A quantity of hand's motion is the biggest. As for the shoulders, an abecedarian is easy to cause a mistake most. Therefore that we measure them closely is demanded. Thus the four points are used optical sensors and an ultrasonic sensor. The other points acquired the coordinate with USB cameras.

(b) Method of measuring action timing

Shahou-Hassetu repeats arm's movement and arm's stillness. In short, Shahou-Hassetu repeats arm's movement and arm's stillness. For example, Yugamae stillness fixed time, next Hikiwake move fixed time. Fixed time is fixed in each motion. We can get high evaluation so as to be close the time in Kyudo' promotion examination. Therefore moving time and standing still time are important when learning Kyudo.

The evaluation of action timing in the evaluation system uses optical sensors of arms in Figure8 of a3 and a4. We detected movement and standstill from coordinates of arms, and acquired motion's time and standstill's time in each element.

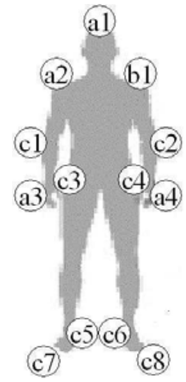

Figure8. The detecting points

(C) Evaluation method to learner's motion

The system evaluates angles of Goju-Jumonji and Sanju-Jumonji, and action timing of eight elements.

(a) Evaluation method for two Jumonji

We calculate a score in each element of Shahou-Hassetu. We decide a perfect score of one element is one hundred, and calculate by demerit mark system. We calculate demerit mark of eight Jumonji, and deduct points of one hundred. The action timing is T[s] and measures learner's motion every 10[ms]. Positions of Jumonji n are α_{nt} in t [ms], and angles of Jumonji n are β_{nt} in t [ms]. Score P is computed by a formula (4) when a position of sample motion is β'_{nt} and an angle of sample motion is α'_{nt}.

$$P = 100 - \sum_{n=1}^{J} \frac{\sum_{t=0}^{100T} \left(\left| \alpha_{nt} - \alpha'_{nt} \right| + \left| \beta_{nt} - \beta'_{nt} \right| \right)}{100T} \tag{4}$$

(b) Evaluation method for action timing

Even a brad folder of Kyudo does not always performed in the same time. There is constant width for time. We use the width and decide allocation of points. If a learner's time is time in the width, and it is one hundred. Whenever 0.06 second slips off, ten points deduct points.

VII. EXPERIMENT

(A) Experiment

TurnA-space software is used for capturing learner's motions with USB cameras. TurnA-space software is the software that can detect objective coordinates from the color-feature of the object to the arbitrary objects on a screen.

2 dimensional coordinates that get from TurnA-space are converted into 3 dimensional coordinates by DLT method. The points where motion speed is fast used optical sensors "HiBall-3100 (3rdTech company)" and an ultrasonic sensor "InterTrax2 (Inter Sense company)", and measured the

points. We used Visual C++ DirectX SDK for implementation of interface as development environment.

(B) Consideration for a result in experiment of the system

The experiment is for five subjects. A learning object is Kyudo. Two learners used an evaluation system, and they trained Kyudo without using the image training assist system. Three learners used an evaluation system and the image training assist system, and trained Kyudo. Five learner trained Kyudo fifteen times. Figure 3 is shown a change of score average of the former and the latter, and a change of a number of points. A score average from the first time to the last time had difference of 25 points between the image training assist system users and do not users. A number of points increase a evaluation score in the early stages. We can think that the learner trains the motor skill while putting attention in plural points in one time of trial. Moreover, a number of points decrease by degrees the latter half. We can think that the learner learns motor skill without being conscious of. We could show that learner did more effective learning by using the system. However, there were some problems that learning time is long, so the recording took time.

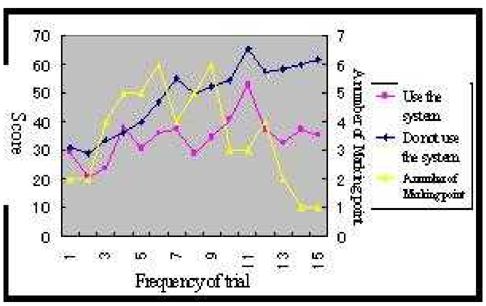

Figure9. The transition of score and point number

Table 1 is shown results of the questionnaire after the motor skill learning. The questionnaire had five learners reply by five questions. (5: think of very so, 4: think of so, 3: cannot think which, 2: do not think, 1: do not think at all) We got more than 4 for all questions. In addition, opinions ware "It is difficult to record in the just right time while looking the motion."" There had better put expression of a point except a ball."

A learner was conscious of the motor senses that he/she felt and motion images by using the image training assist system while training the motor skill. And the learner recorded properly them, and could make useful self-analysis. However, the system has problems that the difficulty of action timing of punting down points, the scantiness of point expression. The next challenges of our study are to grope for the expression method that the learner is easily imagined. As a solution means, that the learner look slowly history and that the learner is automatic to hit a tag in learning are put up. We have to implement recording function by an arrow in order to express information which direction and how much power.

Table1. Results of the questionnaire

Questionnaire items	Average
Could the sense record function able to record feeling while learning according to the image?	4.7
Could the sense record function record motor skill that aimed newly according to the image?	4.0
Could the display of the motor skill evaluation useful for the selection to comparison the history?	4.7
Could it useful for the self-analysis to inspect sense and motion at the same time when the comparison was referred?	4.7
Was the function to display modified information while learning useful to the action timing?	5.0

VIII. CONCLUSION

This paper proposed image training assist system for the motor skill learning, and adapted the system to learning Kyudo (Japanese traditional archery) as one of motor skill learning for evaluation. The system has functions that are recording function of the motor sense and the modifying information, comparison function of the motor senses and the motions. We implemented the image training assist system, and evaluated the system by experiments. As a result, we could show the effectiveness of the learning that put consciousness in the motor sense by a proof experiment.

However, it takes long time that the learner records a point in the sense by recording function. And it needs not only expression of the ball position but also the expressing of the power direction and the power strength. The next challenge of our study is to implement functions that history function of reading slowly, recording function of the expression method that the learner is easily imagined and automatic function to hit a tag in training the motor.

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