# Development of a simulation VR system for *kyudo* beginners to train the shooting form empty-handed or with a rubber practice bow

Shoei Nakamura[1] and Keita Ushida[1,*]

[1] *Kogakuin University, 1-24-2 Nishi-shinjuku, Shinjuku, Tokyo 163-8667, Japan*

## Abstract

The authors developed a simulation VR system for *kyudo* beginners to train the shooting form. Before *kyudo* beginners can practice with a (real) bow, they train the shooting form empty-handed and with a rubber practice bow. The system is expected to be used during this period. The user wears the HMD and practices in the training hall in the VR space empty-handed or with a rubber bow. The user's shooting form is measured, and when the form is appropriate (compared to the *kyudo* expert's form equipped in the system), the arrow hits the target in the VR space. Whether the arrow hits the target depends only on the user's forms, which reflects *seisha hitchu* ("true shooting, certain hitting"), i.e., the importance of the shooting form. In addition, when the arrow hits the target, the user feels a sense of fulfillment and is motivated to continue practicing *kyudo*.

## Keywords

*kyudo*, Japanese archery, shooting forms, training with VR

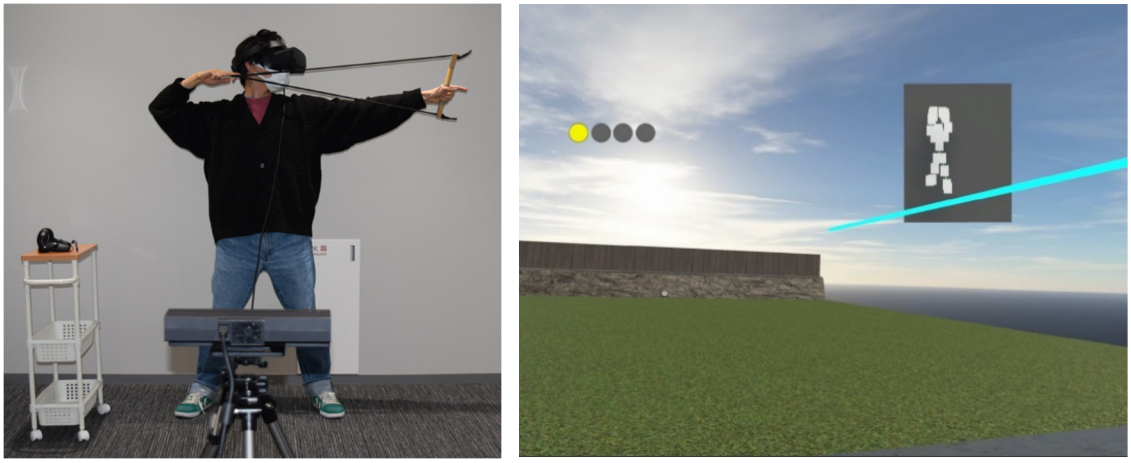

**Figure 1:** The system at work: A user is training the kyudo shooting form with the developed system (left). The training hall and the skeleton of the user are displayed to him/her through the HMD (right).

## 1. Introduction

When you first start *kyudo* (Japanese archery), you can't shoot an arrow with a (real) bow. You must learn the shooting form, how to control your body for shooting, and so on. Therefore, you must train the shooting form empty-handed and with a rubber practice bow for six months to a year. During this training, you practice without arrows and a (real) bow. You may find it hard to continue practicing *kyudo*.

In this paper, the authors study the training of the shooting form in the period described above, referring to the previous works on practicing *kyudo* shooting form. The authors also focus on motivating the user in this period. The authors expect the user to be motivated when his/her appropriate form make the arrow hit the target. This reflects a famous *kyudo* phrase *seisha hitchu* ("true shooting, certain hitting"). Though the user doesn't equip an arrow or a bow, s/he can make the arrow hit the target in the VR space. This idea will let the user know the importance of the shooting form and motivate him/her (moreover, this concept is a kind of gamification).

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* Corresponding author.
j019216@kute.tokyo (S. Nakamura); ushida@cc.kogakuin.ac.jp (K. Ushida)
0000-0003-3972-4332 (K. Ushida)

## 2. Related Works

Many studies on sports, including *budo*, deal with the practice and evaluation of the form. As for *kyudo*, there are also studies on the form. In [1], an evaluation of the user's shooting form with motion capture using a Kinect sensor is developed. In [2], the advice for improving the form is superimposed on the user's image in the display calculated from his/her motion data. In [3], the evaluation and the advice to improve the form are provided from the measured form in real time. In [4], the user examines his/her form by superimposing and comparing the model form and his/her form with an HMD. In [5], the user learns the shooting form by observing the images of the model form and adapting his/her form to the model. In [6], a self-training system of kyudo shooting posture using a computer vision method is proposed. In [7], a training method is proposed in which the user makes a sketch doll pose in the shooting form and poses by him/herself as making the doll pose.

VR-based *kyudo* shooting form training systems have also been developed. In [8], a VR-based shooting form training system using multi-modal information is proposed. In [9], the user trains the shooting form with an HMD and a VR controller. In [10], a VR training system with which the user can correct his/her shooting form in real time with motion trackers is developed.

In addition to measuring and evaluating the shooting form, the remarkable feature of the authors' system is that the appropriate form makes the arrow hit the target in VR space. Hitting the target with the arrow is the real charm of *kyudo*. This feeling will lead to a sense of fulfillment and motivation to practice *kyudo*.

## 3. The Flow of Shooting Form Training with the System

Those who train the shooting form empty-handed and with rubber bows before they are permitted to equip real bows are the expected users of the developed system. They have learned the overview of the shooting form.

The user wears an HMD, stands against the sensor, and trains the shooting form empty-handed or with a rubber bow. There is a training hall and a target in the VR space displayed in the HMD. At the top right of the view, the user's skeleton measured by the sensor is shown (Figure 1).

The user trains following the eight-step movement of the shooting form (*shaho hassetsu*). After the user completes the setup for the shooting (*ashibumi*, *dozukuri*, and *yugamae*), the measurement starts. Thus, the last five steps (*uchiokoshi*, *hikiwake*, *kai*, *hanare*, and *zanshin*) are measured and evaluated. As the movement progresses, the evaluation indicators (at the top left of the view) turn on. The green lamp represents qualified, and the yellow lamp represents unqualified.

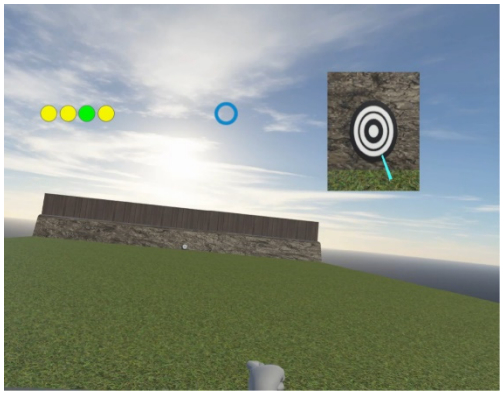


**Figure 2:** When the user's shooting form is appropriate, the arrow in the VR space hits the target.

After the shooting motion (*hanare* and *zanshin*) is completed, the arrow in the VR space is shot. The arrow hits the target when the total score of the four movements (*hanare* and *zanshin* are evaluated into one) is higher than the qualifying score. Whether the arrow hits the target is closed-up in the view and indicated by "○" (hit) or "×" (miss) (Figure 2). Thus, whether the arrow hits the target depends on the appropriateness of the shooting form. Therefore, when the user qualifies for the current goal, i.e., his/her shooting form is appropriate, s/he can make the arrow hit the target in the VR space.

Finally, the detailed evaluation and the comments are displayed. The user can restart the training by pressing the button on the VR controller.

## 4. Details of the System and Its Behavior

### 4.1. Implementation environment

The authors developed the system using Unity on Windows. The HMD is Oculus Rift S, and the sensor is Microsoft Kinect v2.

### 4.2. The shooting form the user trains with the system

The *kyudo* shooting form consists of eight steps (*shaho hassetsu*): *ashibumi*, *dozukuri*, *yugamae*, *uchiokoshi*, *hikiwake*, *kai*, *hanare*, and *zanshin*. In the developed system, the user trains mainly *uchiokoshi* (raising the bow), *hikiwake* (drawing apart), *kai* (the full draw), *hanare* (the release), and *zanshin* (the remaining body or mind). In the system, *hanare* and *zanshin* are lumped together because the time of *hanare* is very short.

### 4.3. The view from the user

The system displays the training hall to the user, as shown in Figure 1. In addition, in the training, the skeleton of the user measured by the sensor (at the top right

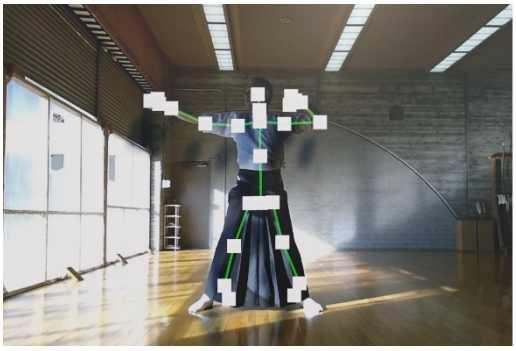


**Figure 3:** The prerecorded model form by a *kyudo* expert.

of the view) and the evaluation indicator (at the top left of the view) are displayed. The four indicators represent the evaluation of *uchiokoshi*, *hikiwake*, *kai*, and *hanare* and *zanshin*, respectively. The user can see the position of the hands and the arrow which follows the position of the hands.

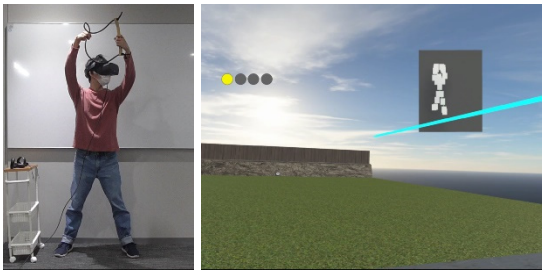
### 4.4. Training the shooting form and its evaluation

The user presses the button on the VR controller to start the training (the controller should be within reach). The user places the footing (*ashibumi*), forms the body (*dozukuri*), and readies the bow (*yugamae*). These setup steps are out of evaluation.

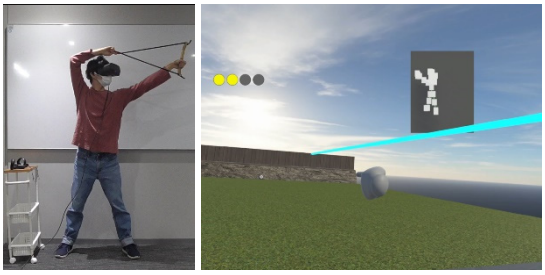
When the user starts *uchiokoshi*, the system begins to measure and evaluate the shooting form. The user's shooting form is compared with the prerecorded model form performed by a 6-dan *kyudo* expert (Figure 3). The evaluation points are: the angle between the torso and the right upper arm from the side view, the angle between the torso and the left upper arm from the side view, the angle of the right elbow, the angle of the left elbow, the angle between the torso and the armpit, the angle between the back and the chest, the positions of both hands, the positions of the shoulders, and the inclination of the body. Most items are angles because they don't depend on the user's physique. The score is higher when the difference between the measured value of the user and that of the model is slighter.

The scores of each step (*uchiokoshi*, *hikiwake*, *kai*, and *hanare* and *zanshin*) are indicated by the lamps at the top left of the view. The green lamp represents qualified and the yellow lamp represents unqualified.

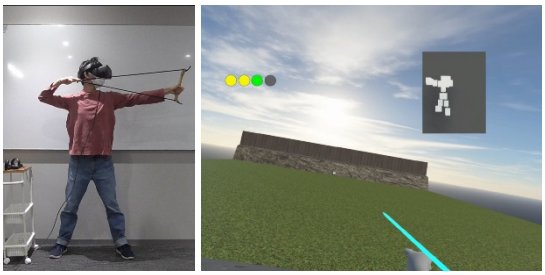
After *hanare* and *zanshin* motion, the arrow in the VR space is shot. When the total score of the four steps is higher than the qualifying score, the arrow hits the target. (when the total score is lower, the arrow doesn't hit the target). The target is closed-up at the top right of the view, as shown in Figure 2. Whether the arrow hits the target is indicated by "○" (hit) or "×" (miss). In Figure 2, though *uchiokoshi*, *hikiwake*, and *hanare* and *zanshin* are unqualified, the arrow hits the target because the total score is qualified.



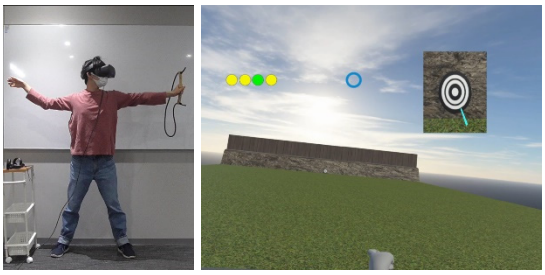
(a) *Uchiokoshi*



(b) *Hikiwake*



(c) *Kai*



(d) *Hanare* and *zanshin*

**Figure 4:** A user training with the system (the left column) and his view (the right column).

Figure 4 shows a user training with the system and his view. The cyan line is the arrow and the hand positions are displayed near it. As shooting progresses, the indicators at the top left turn on. Finally, his form made the arrow hit the target.

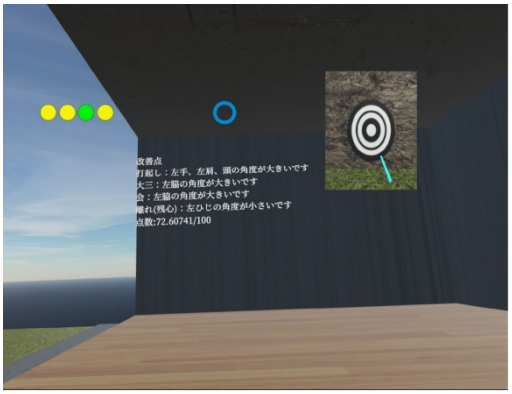



**Figure 5:** The detailed score and the comments are displayed on the wall of the training hall.

After *hanare* and *zanshin* is finished, the detailed score and the comments are displayed on the training hall's wall (Figure 5).

By pressing the button on the VR controller, the training restarts.

## 5. Test Drive and Usability Study

### 5.1. Test drive

A test drive was carried out by one of the authors who was experienced in *kyudo*. Figure 4 shows his training. Those who have mastered the *kyudo* shooting form can make the arrow hit the target because their shooting forms are appropriate.

### 5.2. Usability Study

The authors carried out a usability study. The authors checked that the system was easy for everyone to use before it was extensively tested by *kyudo* beginners and experienced *kyudo* players.

Ten participants aged 18–20 tried the *kyudo* training using the system. All of them had no *kyudo* experience, and they tried the training after the authors showed and explained the form. The authors observed their trials and received comments from them

All of them were able to train without problems. However, none of them were able to make the arrow hit the target. Their inability was inevitable because they had to acquire the shooting form to a sufficient level to make the arrow hit the target. Nevertheless, their smooth training indicated that the system's usability was appropriate.

Two of them were familiar with VR experiences and gave detailed comments: The feedback (displayed hand positions and marking indicators) was useful for smooth training. It was better to display the model form (this indicates that integration of a presentation method like [4] will be useful for the users at a lower level than expected).

No usability problems were found. The next step is to evaluate the system by *kyudo* beginners and experienced *kyudo* players.

## 6. Conclusion and Future Works

In this paper, the authors reported a VR simulation system for training the *kyudo* shooting form. The appropriate form makes the arrow hit the target in the VR space, which reflects *seisha hitchu*. The real charm of making the arrow hit the target will motivate the users who haven't been permitted to equip the real bow.

Currently, the usability of the system has been tested. After this, improving the training quality and the practicality of the actual training will be studied. The former is to improve the method of measurement and evaluation referring to the related works. The latter is the trial and evaluation by *kyudo* beginners and experienced *kyudo* players. The effectiveness will also be studied in the long term.

Furthermore, considering the study in Section 5.2, the system can be used as VR content to introduce *kyudo* (such as [11]). The authors also take this potential into account.

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