Quantitative Analysis of *Iaido* Proficiency by Using Motion Data

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Abstract

The purpose of this research is to make a quantitative analysis of Iaido (the Japanese art of using the Japanese sword) proficiency with multivariate data analysis. We carried out experiments of motion capture on Kirioroshi (a straight overhead slash) movement of Roppon-me (a sword thrust using two hands) in Iaido. We can analyze the proficiency of an Iaido practitioner by conducting PCA (Principal Components Analysis) and cluster analysis of parameters of body movement. In addition, it is expected that our research will help Iaido practitioners and masters with Iaido training through giving new information on Iaido movements.

1. Introduction

Recently, martial art has been frequently studied and analyzed using a motion capture system, but systematical researches on the motion of *Iaido* has been rarely analyzed. *Iaido* is the Japanese art of drawing the Japanese sword, the associated with controlling movements of striking or slashing, and then replacing the Japanese sword in its scabbard.

There are several studies in the literature relating to martial art analysis through the measurement of body motion, for instance, the characteristic of *Wing Chun* movement [1], training systems [2], and foot movement analysis for Tai Chi [3], etc. However, quantitative analysis of proficiency of an *Iaido* practitioner has not been accomplished yet.

In the following study, we focused on the movement called *Kirioroshi* (a straight overhead slash) of *Roppon-me* (a sword thrust using two hands) of *Iaido* (see Figure 1). The *Iaido* practitioner needs adequate training to control the speed of body and arms to undertake the *Kirioroshi* movement. In particular, the *Kirioroshi* movement of *Roppon-me* requests the *Iaido* practitioner to carefully manage the slash movement and the transition and retainment of body movement.

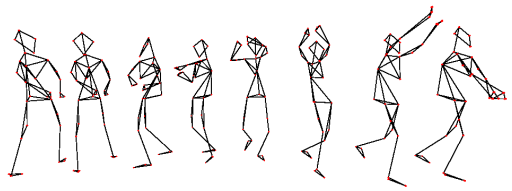

Figure1. *Kirioroshi* movement of *Roppon-me*

In this research, we aim at quantitatively comparing the proficiency of an *Iaido* practitioner by conducting PCA and cluster analysis of body motion data.

2. Method

In this research, we carried out experiments on the *Kirioroshi* movement of *Iaido* by using a motion capture system.

2.1. Subjects

Six students (age = 24.2±4.9 years, body height = 167.7±5.3 cm, body weight = 57.8±5.7 kg, career = 2.5±2.1 years) of *Iaido* were recruited as subjects in this experiment. Four subjects (A, M, T, K) have a skilled level and the other subjects are beginners (C, S). Skilled A was not trained in *Iaido* for the 3 months prior to capturing motion data.

2.2. Procedure

We measured the *Iaido Kirioroshi* movement of *Roppon-me* by using a motion capture system.

Thirty-two markers were attached on the body of each subject in order to capture motion data using an Eagle-Hawk system (Motion Analysis Corp.). This system incorporates 14 cameras detecting the 19mm markers attached to a subject who moved in a 3m × 3m area. We captured data with a sampling rate of 60Hz and recorded each performance three times for each subject.

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Table 1. Definition of parameters

No.	Parameter	Definition
1	Center of gravity	Using 19 virtual markers calculated by 32 markers
2	Velocity of right hand	Using right hand marker
3	Angle of root	Angle between chest and neck from root
4	Angle of neck	Angle between head and chest form neck
5	Angle of right pelvis	Angle between right shoulder and left hip from right hip
6	Angle of left pelvis	Angle between left shoulder and right hip from left hip

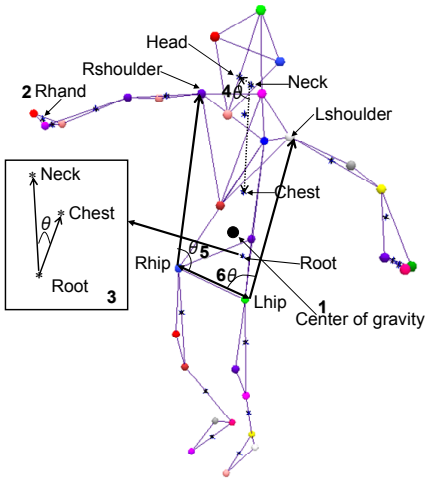


Figure 2. Definition of each parameter.

2.3. Data analysis

A detailed definition of parameters is summarized in Table 1 and location of each parameter is illustrated in Figure 2. Each captured data for each parameter is normalized before the analysis of the *Kirioroshi* movement. PCA was used to reduce the multidimensionality of the parameter set prior to extracting feature parameters of measuring the proficiency of the subjects. We then used cluster analysis to classify the proficiency of subjects using the feature values calculated by PCA.

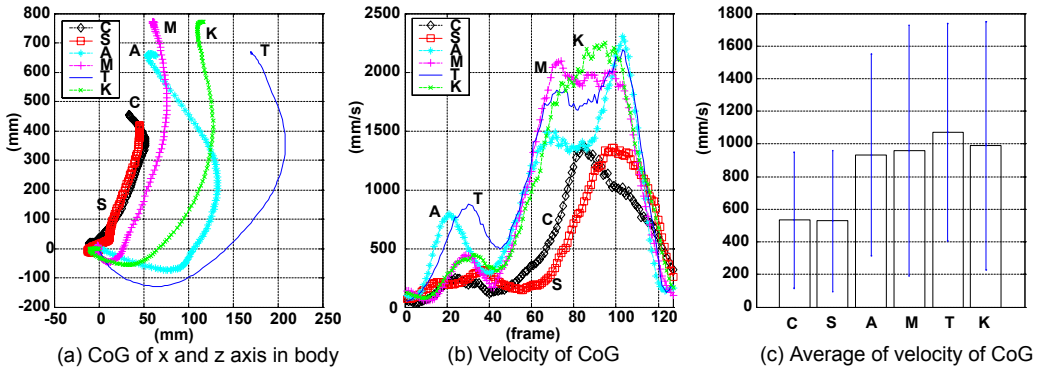
3. Results and discussion

In this research, we quantitatively compared the proficiency of subjects by conducting PCA and cluster analysis of body motion data. In the following section, we will describe the result of our analysis of the *Kirioroshi* movement of *Roppon-me*.

3.1. Center of Gravity (CoG)

Firstly, we quantitatively analyzed the CoG of the subjects doing *Kirioroshi*. The CoG can be used to indicate the transfer and retainment of body movement. The position of the CoG in each body segment can be calculated by using anthropometric data (segment weight and segment length) as proposed by *Matsui* [4].

Figure 3 (a), (b) and (c) indicate the transfer of CoG of each subject, the velocity of CoG and the average of velocity of CoG, respectively. Skilled level subjects have more transfer of CoG than that of the beginners C and S (see Figure 3 (a)). At the moment of the slash movement, skilled subjects have a velocity variation of CoG of approximately 600 mm/s greater than that of beginners C and S (see Figure 3 (b) and (c)). Skilled level *Iaido* practitioners use the *Iaido* technique called *Jo-ha-kyu* while executing *Kirioroshi*. *Jo-ha-kyu* is characterized by a sense of rising motion; for instance, from a small slash to the larger slash. Beginners C and S have less transfer distance and CoG velocity



(a) CoG of x and z axis in body (b) Velocity of CoG (c) Average of velocity of CoG

Figure 3. Center of gravity during *Kirioroshi*.

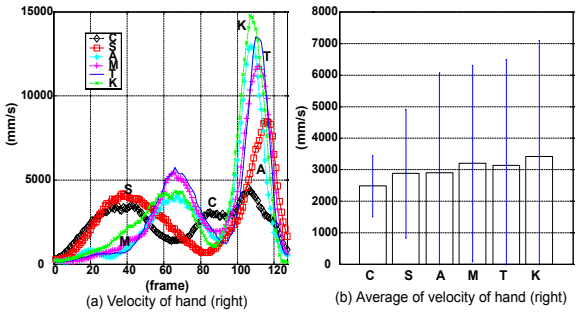


Figure 4. Velocity of right hand during *Kirioroshi*.

compared to the skilled subjects, because they did not use the *Iaido* technique of *Jo-ha-kyu* and their lack of *Kirioroshi* training with the Japanese sword.

3.2. Hand velocity

Secondly, we compared the velocity of the right hand of subjects when executing *Kirioroshi*. The right hand leads the slash while the left provides support of the Japanese sword. This method allows the tip of the sword to achieve maximum speed during the slash.

In this experiment, we used a wooden sword of 500g to ensure the safety of the subjects. Figure 4 (a) and (b) indicate the velocity of right hand of each subject, and the average of velocity of the right hand, respectively. Skilled subjects have more velocity of the right hand than that of beginners C and S (see Figure 4 (a)). During the slash movement, the velocity variation of the CoG of skilled subjects was approximately 5000~10000 mm/s greater than that of beginners C and S. Therefore, skilled subjects act quickly, i.e. about 3000mm/s, but beginners C and S act slower at about 2500 mm/s velocity (see Figure 4 (b)). The difference in velocity of the right hand of subjects is related to their career length and training time in *Iaido*.

3.3. Angles of root and neck

Thirdly, we compared the angles of the root and neck of subjects while executing *Kirioroshi*. These angles are related to the stabilization of the upper half of the body. The difference in angle variation of the root in subjects was approximately 4~8° (see Figure 5(c)). Beginner C had less standard deviation than that of the other subjects due to the low velocity of the subject's CoG and right hand (see Figure 5 (c)). As shown in Figure 5 (d), skilled subjects had a variation of neck angle of approximately 130°, but the beginners C and S had 93° and 137° variation, respectively.

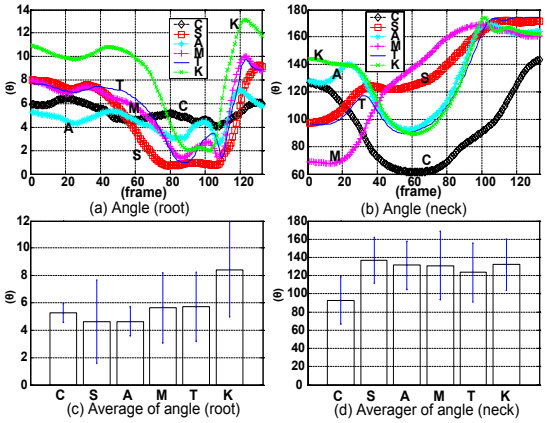


Figure 5. Angles of root and neck during *Kirioroshi*.

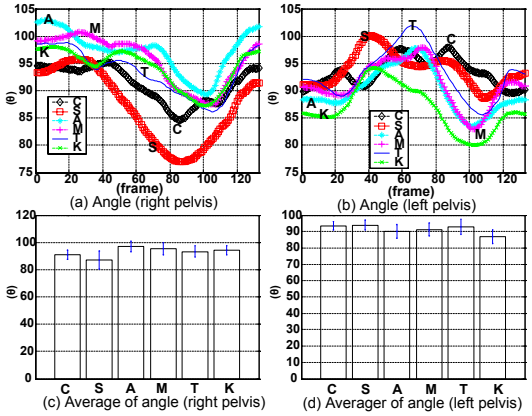


Figure 6. Angle of pelvis during *Kirioroshi*.

3.4. Angle of pelvis

Next, we compared the angle of the subject's pelvises during *Kirioroshi* execution. The angle of the pelvis is related to the stabilization of the lower half of the body on *Kirioroshi*. In particular, beginners C and S have instability of the right pelvis at the step of the right leg (see Figure 6 (a)). Beginners C and S have more angle variation of the pelvis than that of the skilled subjects (see Figure 6 (c) and (d)).

3.5. PCA

Next, we used PCA to reduce the multidimensional parameter sets to a lower dimensionality for extracting the feature parameters for measuring proficiency. The parameters of Table 2 and the standard deviation of each parameter were used as sample data for PCA.

The PCA scatter plot for each subject is illustrated in Figure 7. We have only plotted two PCA axes because the cumulative proportion of PC1 and PC2 is approximately 80% of the entire data set. PC1 has

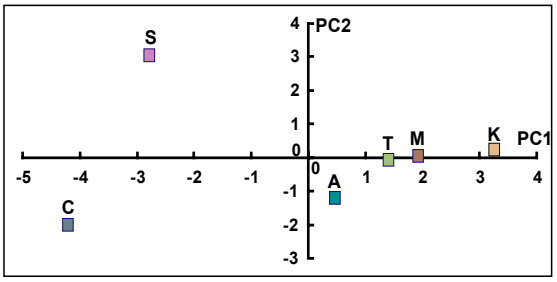


Figure 7. Results of PCA.

highly positively correlated to the standard deviation of velocity of CoG and the standard deviation of velocity of the right hand. PC2 has highly positively correlated to the standard deviation of the angle of the right pelvis and the standard deviation of the angle of the root. PC1 is related to the velocity of the body during the slash movement, while PC2 is related to the stabilization of the body.

Therefore, we can say that the proficiency of subjects can be classified by the velocity of transfer of the subject's CoG and the stabilization of the angle of the subject's root and pelvis while performing *Kirioroshi*.

3.6. Cluster analysis

Finally, we used cluster analysis to classify subjects corresponding to the proficiency level by using the feature values of PC1 and PC2 calculated via PCA. To run cluster analysis, we used Euclidean distance to calculate distance of data and Ward`s method to determine group.

The result of cluster analysis is illustrated in Figure 8. Subjects were classified into two groups. Beginners C and S belong to the second group and the skilled subjects do to the first group. Also, the skilled subjects were further classified into career and grade groups.

From the analysis results, we notice that the proficiency of an *Iaido* practitioner can be classified by using feature parameters of the velocity of body motion and the stabilization of the body while performing *Kirioroshi*.

We consider that beginners of *Iaido* can not essentially perform the stable *Kirioroshi*, because they did not build an appropriate body for *Iaido* and their lack of *Kirioroshi* training with the Japanese sword. Therefore, they require an adequate training of *Iaido*. The knowledge extracted from PCA and cluster analysis is able to discriminate the proficiency between skilled practitioner and beginner. We are convinced that these methods are out putting appropriate numerical value in a new standard when executing *Kirioroshi*. In particular, *Iaido* master often pointed

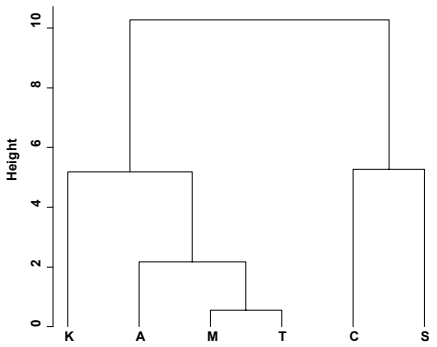


Figure 8. Results of cluster analysis.

out the stabilization of body during training. Therefore, we can say that using the information gained from our research we can get an effect that is closet to training of master while performing *Kirioroshi*.

4. Conclusion

In this research, we carried out the quantitative analysis of *Iaido* proficiency by conducting PCA and cluster analysis of body motion data. As a result, we verified that a skilled subject has more velocity of CoG and right hand movement and has a more stabilized body than that of a beginner when performing *Kirioroshi*. Therefore, we found that the feature values used in analysis of subjects can be used to classify the proficiency of an *Iaido* practitioner by using PCA and cluster analysis.

5. Acknowledgements

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