Augmented Reality System for Measuring and Learning Tacit Artisan Skills

Atsushi Hiyama[1], Hiroyuki Onimaru[1], Mariko Miyashita[2], Eikan Ebuchi[3], Masazumi Seki[3], and Michitaka Hirose[1]

[1] Graduate School of Information Science and Technology, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, 113-8656 Tokyo, Japan
[2] Tamagawa University, 6-1-1, Tamagawagakuen, Machida-shi, Tokyo, Japan
[3] Kochi Prefectural Paper Industry Technology Center, 287-4, Hakawa, Ino-cho, Agawa-gun, Kochi, Japan
{atsushi,oni,hirose}@cyber.t.u-tokyo.ac.jp

Abstract. Many traditional artworks in Japan are now facing the issue of raising successors to conserve their culture. It usually takes decades to learn artisan skills in conventional way. We propose a learning system using augmented reality technology to help transferring techniques in one of the Japanese traditional papermaking *kamisuki*. First, we measured the expert's motion and extracted tacit skills. Second we examined the relation between extracted motion and paper quality by software simulation. Finally, we developed a projection based augmented reality system that visualizes experts' tacit skills to leaners when they train papermaking. As a result, the system helped enabling learner to obtain techniques to improve the quality of paper in short time period.

Keywords: Augmented reality, Tacit knowledge, Physical skill training, Cultural heritage.

1 Introduction

Industrialization and low birthrate in Japan accelerated the declining in inheritance of many traditional arts. Conventionally, skills of traditional arts are transferred by word-of-mouth between a master and apprentices. Decades of efforts are required to learn those techniques for apprentices. Within this learning framework, only limited number of apprentices can learn the craftsmanship. This process has demanded great tolerance and made inheritances of traditional arts extremely difficult.

Recently, there have been efforts to record those artisan skills in textbook or video. We can learn the basics of traditional arts a little easier than before. However, those media can hardly transfer artisans' techniques that relates to fine control of bodies, tools, and environmental conditions. Several researches have been done on conservation of traditional craftwork skills in digital way. There is plenty of research on digital archiving of tangible cultural heritage such as paintings, craftworks and

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buildings [1, 2, 3]. Some researches focus on the artistic movements such as dance [4]. However, focus of these studies is on the existing art objects or artistic movements themselves, not on the artisanship to create those art objects. Saga et al. developed a unique system to transmit calligraphic skills using haptic feedback [5]. Our approach takes a similar attitude toward preservation and transmission of skills, but in a more integrated way with various sensors, taking deeper look at the tacit knowledge of experts numerically. We have created an integrated framework for the digital preservation of artisanship [6, 7]. In this paper, we explain our framework for digital archiving of craftwork skills, and show a verification experiments in which we applied the system to a Japanese traditional craftworks, *kamisuki*.

Kamisuki is a technique to craft traditional Japanese paper, washi. *Kamisuki* is starts from scooping the liquid, which is mixture of water, pulp of *kozo,* and glue, by wooden tool called *sukigeta*. Then swing *skigeta* back and forth to circulate scooped liquid over the *sukigeta* in order to spread pulp of *kozo* over *sukisu*, which is a bamboo mesh clipped inside the *sukigeta*, and accumulate it to form a piece of paper (Fig. 1). Formerly, we developed a wearable display system that provides an experience for learner from first person view of an expert [8]. This training system achieved a remarkable speed-up in learning of basic movement in *kamisuki* for beginner. As a next step, we made progress into training of paper quality improving technique.

Fig. 1. Three main movements in Japanese papermaking; scooping, swinging and draining (*from the left*)

2 Proficiency and Handcrafted Paper Quality

We measured uniformity of paper between three persons in different level. Subject A is a holder of special technique to be preserved, authorized by Ministry of Education, Culture, Sports, Science and Technology. Subject A has refined his *kamisuki* skill for 30 years. Subject B has 10 years of experience in *kamisuki*. Subject C is nearly a beginner who trained basic skill of *kamisuki* with our wearable display system [8].

In order to evaluate uniformity of paper, we cut square 10 cm on a side from the top and the bottom of a paper and compared the weights of these two pieces. If paper is made more uniform the difference will become smaller. We asked subjects to make 9 pieces of paper and measured the difference of each paper (Fig. 2).

As a result, we found that the uniformity improves in the order of subject A (30 years of experience), B (10 years of experience), and C (beginner). Higher skill leads to the high quality of papermaking.

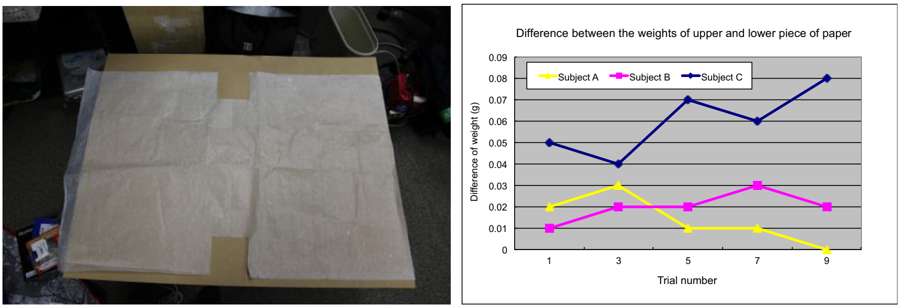

Fig. 2. Measured the difference of weight of 10-cm-square pieces cut off from top and bottom side of a paper (*left*). Results in difference of weight of each subject (*right*).

3 Analyzing Expert's Skill of Making Uniform Paper

3.1 Measuring Unobservable Difference in Motion of *Sukigeta*

A piece of paper is formed by a set of swinging movement of *sukigeta*. Therefore, difference in this movement of each subject made the difference in uniformity of paper. In order to extract the characteristics of this movement of expert (subject A), we set a laser range sensor (Hokuyo URG-04LX) over the *sukigeta* to visualize detailed movements of *sukigeta* (Fig. 3).

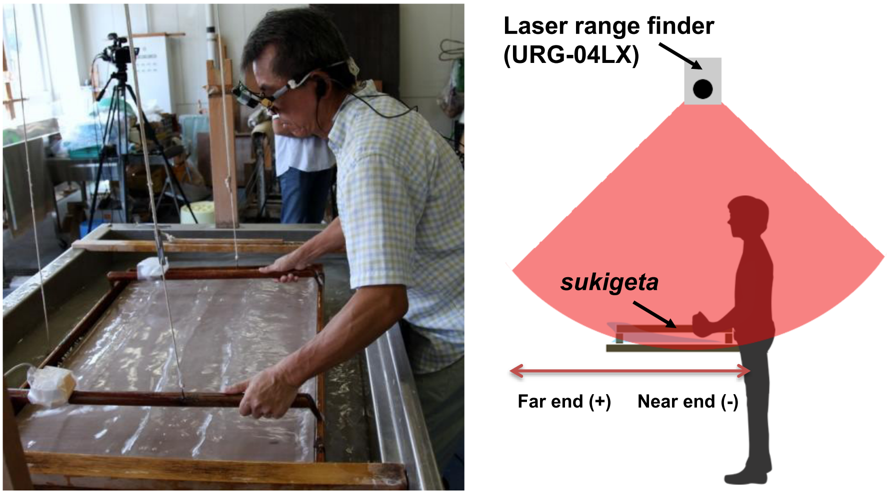

Fig. 3. Experiment setup for measuring detailed motion of *sukigeta*

3.2 Measured Difference in Motion of *Sukigeta*

We measured the movement of *sukigeta* of three subjects mentioned in chapter 2 with the system described in previous section. As a result, remarkable characteristic in motion of *sukigeta* in subject A was found. We found two techniques in manipulating *sukigeta* (Fig. 4).

Technique 1. Center of oscillation of sukigeta is shifting back and forth for three times during a swinging period of papermaking.

Technique 2. Oscillation amplitude of sukigeta is gradually gets larger during a swinging period of papermaking.

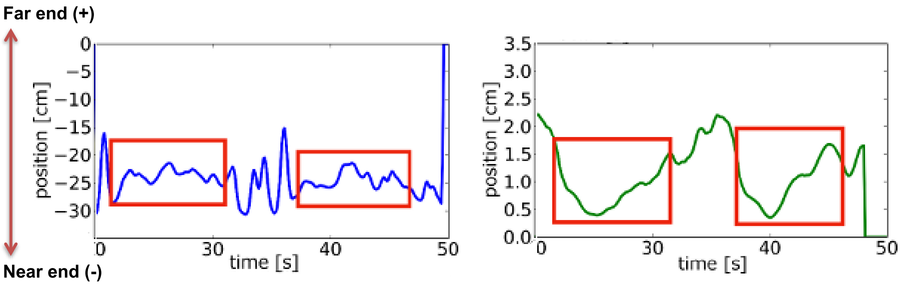

Fig. 4. Two characteristics was found in movement of subject A's *sukigeta*. Swinging period of papermaking is clipped by red rectangles. Shift of center of oscillation (*left*), and width of oscillation amplitude (*right*).

3.3 Relation between Measured Difference and Paper Quality

In order to verify whether two techniques we found in expert's manipulation of *sukigeta* leads to uniformity of crafted paper, we examined the relation between movement of *sukigeta* and accumulation of pulp.

We simulated how fragment of pulp piled up onto a virtual *sukigeta* (Fig. 5). NVIDIA PhysX was used for physical simulation. Each subjects' movements of *sukigeta*, measured by laser range sensor was reflected to the virtual *sukigeta*. Particles located on a virtual *sukigeta* are abstract model of pulp. White particles are illustrating drifting pulp; red particles are precipitated pulp on virtual *sukigeta*.

The results of simulations showed that motion data of subjects A was the best to precipitate particles uniformly onto a virtual *sukigeta*. Subject B's motion data made better uniformity of precipitating than subject C. During this precipitation process, technique 1 (shifting of center of oscillation) contributes in moving groups of particles back and forth; technique 2 (increasing oscillation amplitude of *sukigeta*) contributes in stirring particles to spread drifting particles to avoid precipitating in narrow area as the density of drifting particles get sparse.

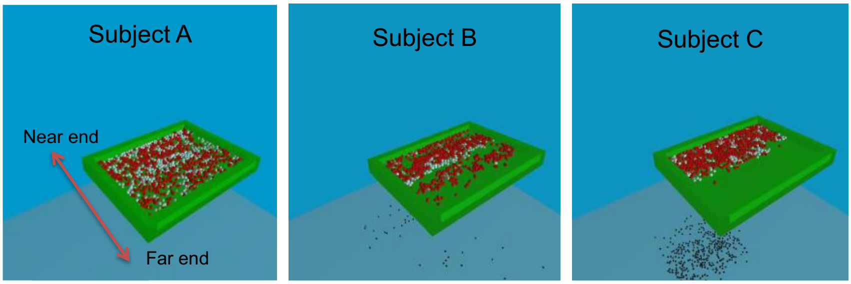

Fig. 5. Physical simulation of precipitating pulp on *sukigeta*

4 Projection Based Augmented Reality Skill Learning System

We developed projection based augmented reality display to coach aforementioned two techniques during the papermaking process. Subject A's motion of *sukigeta* is indicated by augmented reality presentation superimposed onto *sukigeta* (Fig. 6).

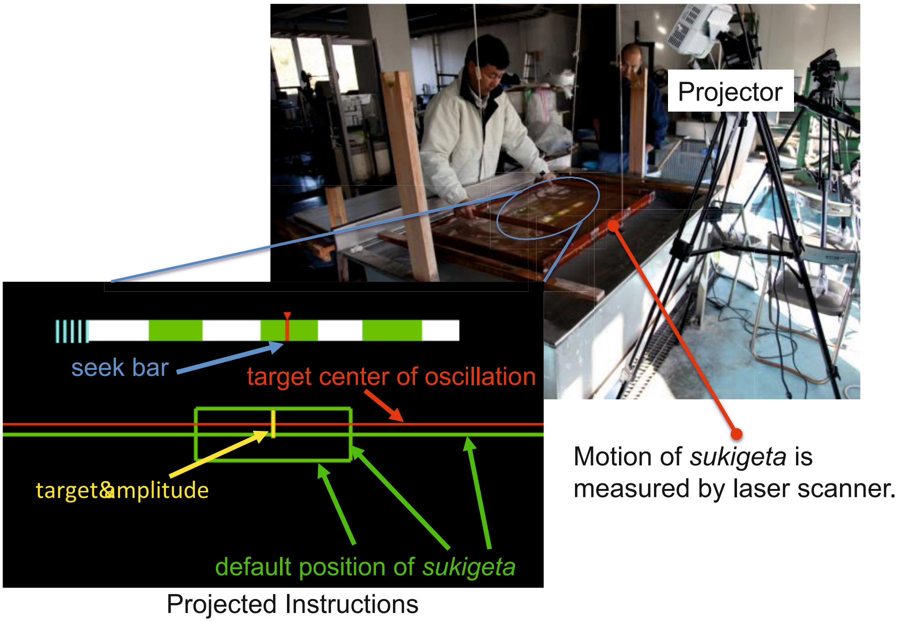

Fig. 6. Augmented reality based learning system. Light green areas in seek bar indicate swinging period during papermaking. Learner must scoop liquid from a sink during white areas in seek bar. Red horizontal line indicates target center of oscillation and length of yellow vertical line indicates the width of oscillation amplitude.

5 Learning Experiment and Result

We conducted training experiment by using developed projection based augmented reality skill learning system to four learners. In addition to aforementioned subject B and C, subject D and E who have same skill level as subject C are added in this experiment. Since the motion of technique 1 varies rapidly, besides presenting raw motion data of subject A, we designed presenting quantized motion data as an indication of target center of oscillation data. In quantized motion data presentation, quantized level of subject A's motion data is gradually changes from 3, 6, and 12. Experiment consists of four sets of trials. In the first trial, subjects craft 3 pieces of paper as a reference data. In second and third trial, subjects craft 8 pieces of paper using either learning method. In the fourth trial, subjects craft 3 pieces of paper without using learning system again (Table 1). Group 1 is subjects who first train with Quantized motion data and group 2 is subjects who first use raw motion data. After 4 sets of trial, we measured the average of difference of weight of 10-cm-square pieces cut off from top and bottom side of a paper in each trial.

Table 1. Learning method for each subject in second trial and third trial

Subjects	*2nd trial*	*3rd trial*
B	Raw motion data	Quantized motion data
C	Quantized motion data	Raw motion data
D	Raw motion data	Quantized motion data
E	Quantized motion data	Raw motion data

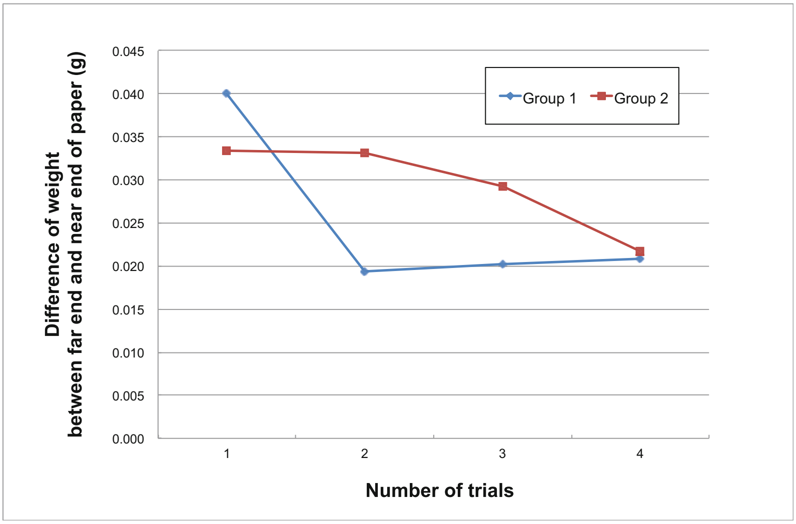

Fig. 7. Average difference of weight of 10-cm-square pieces cut off from top and bottom side of a paper in each trial in each group

As a result, subjects in both group 1 and 2 made a relatively high improvements in paper quality when they used quantized motion data for training. This improvement in skill also remained to each subject even after using proposed learning system.

6 Conclusion

In this research, we measured craftsman's motion of Japanese traditional papermaking and found two remarkable characteristics in motion of expert. We confirmed these two techniques are closely related to quality of papermaking by physical simulation. In order to handing down these two technique, we developed projection based augmented reality display systems that superimposes expert's motion of *sukigeta*. Besides presenting raw motion data of expert, we designed presenting quantized motion data as an indication of target center of oscillation data. From the result of evaluation experiment, quantized motion data presentation made better performance in coaching expert's technique and improved learners papermaking quality. Improved skills of are also successfully remained after using proposed learning system.

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