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Fundamental Study on Using of Motion Confirmation and Gaze Measurement for Preserving Carpentry Technique

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ABSTRACT: This study focuses on 'planing,' a complex carpentry skill that requires extensive training, and investigates both the preservation of techniques and the efficiency of training. As an experimental method, gaze and motion tracking were used to visualize the work of experts and inexperienced participants. The experimental results showed that experts primarily focused on the cutting edge while adjusting the plane and alternated their gaze between the operating point and the plane during planing. Additionally, the expert spent approximately 20% of the time observing the plane. Conversely, inexperienced participants initially focused on the striking point when adjusting the plane but redirected their gaze to the cutting edge after receiving instruction. Furthermore, during the planing operation, gaze dispersion was initially widespread before receiving personal guidance. However, after the guidance, gaze dispersion decreased due to posture corrections. These results suggest that gaze and motion tracking are effective for preserving traditional techniques and improving training efficiency.

KEYWORDS: Carpentry, Inheritance, Eye tracking, motion tracking, planing

1 – INTRODUCTION

1.1 BACKGROUND

To maintain the value of historical buildings, such as cultural properties, over time, proper daily management and regular maintenance are essential.. Therefore, preservation and repair requires deep knowledge, techniques, and skills to convey the value of the building to future generations. In addition, Japan's preservation and repair techniques are known to be at a high level, and the techniques have been designated as intangible cultural heritage. In the course of conducting research on the maintenance and preservation of historical buildings, including important cultural properties, it has become clear that there are many challenges in the proper transfer of skills to repair techniques for maintaining and preserving traditional architecture. Furthermore, in many industries and occupations, the number of skilled technicians is currently decreasing due to the aging and retirement of skilled technicians, a lack of successors, and the advancement of automation and digitalization. In particular, traditional techniques are likely to be lost if they are not sufficiently passed on to the next generation. Therefore, this study aims to visualize and preserve traditional techniques to enable the restoration of traditional buildings such as cultural property buildings in future generations.

1.2 PREVIOUS RESEARCH

Various studies have been conducted on the analysis of carpentry techniques, one of Japan's traditional crafts. Hashitsume et al.[1][2] conducted gaze measurement using an eye-tracking device with a wearable eye camera.Various studies have been conducted, such as those by Kojima et al.[3], who measured six carpenter movementsearable eye camera, focusing on the gaze angle, movement speed, and time required to start cutting in wood cutting skills, comparing skilled and unskilled carpenters, and also listed points that should be taught when acquiring skills based on differences in visual aspects at the start of cutting. In addition, various research is being conducted, such as Kojima et al.[3] who measured six carpenter movements using a device equipped with a muscle displacement sensor and a three-axis acceleration sensor, and Tsukasaki et al.[4],[5] who investigated a method of training instructors using VR to efficiently acquire skills. These studies focused on the efficiency of work acquisition, and currently, studies are also being

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conducted using AI and robots. These studies effectively reduce training time while ensuring structured skill transmission. However, these studies are aimed at training carpenters and passing on skills required for new general construction, and tend to break down work into parts to make it more efficient, eliminating non-essential tasks. However, the loss of these parts affects the passing on of traditional techniques.

1.3 PURPOSE OF STUDY

This study focuses on 'planing,' a skill that is difficult to master and requires extensive training. The aim is to help young carpenters acquire skills more effectively in a shorter period by visualizing their work through gaze and motion tracking, while simultaneously conducting interviews to analyze their awareness of the actions..

2 –EXPERIMENTAL OUTLINE

2.1 TYPES OF MEASUREMENT

This study aims to contribute to visualization and preservation of traditional techniques for future generations. For that purpose, measurements were conducted on master-class carpenters to preserve traditional techniques and on inexperienced participants to identify effective instructional methods for traditional craftsmanship. The subjects included two master-class carpenters with over 20 years of experience and ten students from the Department of Building Environment Systems, School of System Science and Technology, Akita Prefectural University, who had no prior experience. T The measurement consists of eye-tracking using a wearable eye camera attached to the subject and motion analysis recorded by two video cameras installed in two directions to the subject. In addition to the measurement, the consciousness related to the action is also examined by the interview.

2.2 MEASUREMENTS FOR EXPERTS

Figure 1 shows the flow of the experiment for skilled carpenters. The examinee is asked to adjust the plane and perform the action of planing, and gaze measurement, motion tracking and interview are carried out. 2 sides of cedar wood, 120 mm x 120 mm x 1820 mm.

Gaze measurement was conducted using a wearable eye tracker (Tobii Pro Glasses 3). Prior to the experiment, participants' visual acuity and correction methods were assessed to ensure accurate data collection. Measurements were conducted assuming that vision was either normal or corrected using contact lenses. And, the waist bag used by the skilled carpenter was used in order to reduce the incongruity of the examinee on the mounting of the gaze measuring instrument. The experiment is shown in *Figure 2*.

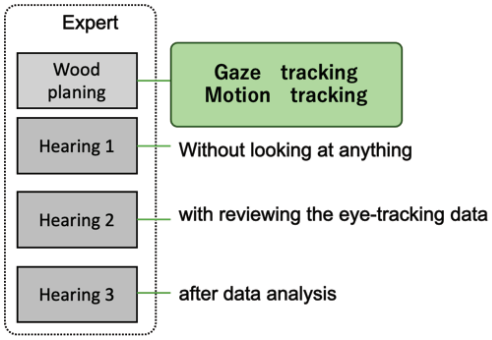

Figure 1 Flow of an experiment for experts

Figure 2 Scene of the experiment

Motion tracking were conducted using two video cameras positioned as shown in Figure 3. One camera was placed in front and the other behind the dominant hand side of the participant. These cameras recorded gaze changes, motion sequences, and posture throughout the experiment from start to finish.

The interview was conducted three times to confirm and classify conscious and unconscious actions. The first interview is conducted on the conscious action right after the test. In the second, after the first interview, the motion which was not confirmed in the first interview is detected, while the motion of the gaze measurement is heard with the subject and the content is confirmed. (Figure 4) In the third session, after the experiment and the analysis of the interview data, the first

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and second interviews are conducted to confirm the contents and to confirm the actions newly detected by the analysis.

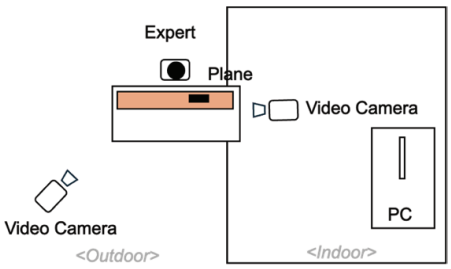

Figure3 Layout of the Experiment with Experts

Figure4 Scene of the experiment

2.2 MEASUREMENTS FOR INEXPERIENCED PARTICIPANTS

The experiment was conducted on inexperienced carpenters to understand the difference between experienced and inexperienced carpenters and to see how the skills of inexperienced carpenters change when inexperienced carpenters receive guidance from an experienced carpenter.

After receiving guidance, the inexperienced carpenters were again fitted with eye tracking devices and their movements of planing and adjusting the plane were measured. The experienced carpenters gave two lessons: first, general instruction, and then individual instruction after the first measurement. As with the experiment on experienced carpenters, these movements were simultaneously measured using a video camera. The experienced carpenters were asked to watch the inexperienced carpenters planing and provide the necessary guidance to improve their skills. The inexperienced carpenters were interviewed about the difficult points and the details of the movements. The experiment was conducted twice (4 people in the first session and 6 people in the second session) with 10 inexperienced carpenters. Due to safety considerations, the subjects were students who had no experience in planing but had experience in woodworking through clubs or classes. From this point forward, students will be referred to as 'inexperienced participants.

The experiment was conducted in three locations: a work area and an interview area for experienced carpenters, a practice area and an interview area for inexperienced carpenters, and a waiting area. (The layout of the work area is shown in Figure 5. Two video cameras were prepared, one in front of the workbench and the other set up to capture the hands of the inexperienced carpenters. The position of the camera for the hands was changed appropriately depending on the dominant hand of the inexperienced carpenters.Measurements were conducted based on the experimental flow shown in Figure 6.

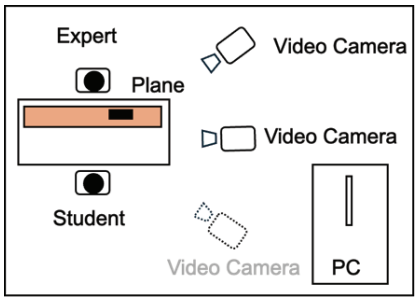

Figure 5 Layout of the Experiment with Inexperienced participants

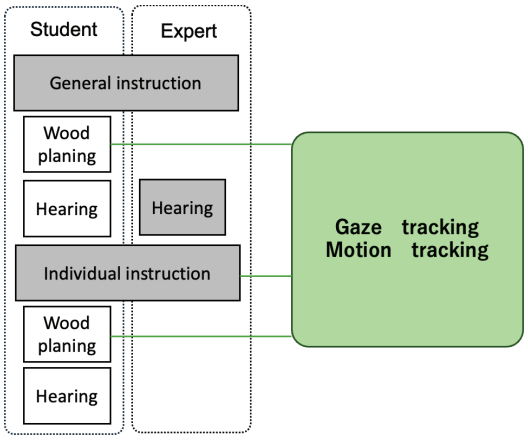

Figure 6 Flow of the experiment with inexperienced participants

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(1) Overall instruction by expert

The skilled carpenter will instruct all participants in the same way on basic plane adjustment and planing. The instruction time will be 10 minutes, and the number of people taught at one time will be 2-3. Since it was necessary to convey the same content to everyone without any excess or deficiency, a meeting will be held in advance with the skilled carpenter to decide on the items to be taught. In order to prevent bias in the instruction given over two days, the skilled carpenter will review the video data of the instruction on the first day before the instruction on the second day, and will provide instruction to unify the content of the instruction.

(2) Planing (1st time)

The inexperienced participants will wear eye tracking devices and adjust and plan the planes one by one. Each person will have 5 minutes to plan. The inexperienced participants will adjust and plan the plane for 4 minutes, and then plan 1 minute with the plane adjusted by the skilled carpenter. At that time, the skilled carpenter will check the planing without instructing.

(3) Interview (1st time)

We interviewed the inexperienced participant and the experienced carpenter for about 10 minutes each. The inexperienced participant was asked about what they found difficult to understand, what movements they found difficult, and what they were able to understand for "how to move their body" and "adjusting the plane." The experienced carpenter was asked about what they were unable to do, what they would teach next, and what they were able to do for "how to move their body" and "adjusting the plane" from the perspective of instruction.

(4) Individual instruction

Individual instruction was given to the inexperienced participant. Although it was individual instruction, it was set to 10 minutes to ensure fairness.

(5) Practice

After the individual instruction, a partition was set up at the inexperienced participant's practice area so that up to three Inexperienced participant would practice in the same place at the same time and not see each other's practice.

(7) Planing (2nd time)

The inexperienced participant was asked to adjust the plane and plan while wearing the line of sight measurement device for 5 minutes. As in (2), the inexperienced participant performed the planing work for 4 minutes while using the plane that he had adjusted, and the last minute was performed with the plane that the experienced carpenter had adjusted. Therefore, if the experienced carpenter judged the plane adjustment to be satisfactory, he would perform the last minute with the plane that he had adjusted. As in the first time, the experienced carpenter was asked to check the planing without instructing him.

(8) Interview (2nd time)

Interviews were conducted for about 10 minutes for both the inexperienced participant and the experienced carpenter. The inexperienced participant was asked about the difficult things, actions, and things that he understood. The interviews with the experienced carpenters were conducted after the inexperienced carpenters' first planing session to extract information on what they would teach them in the next individual training session, and what they had been able to do and what they had not been able to do. In addition, at the end of the session, the carpenters were asked about anything that concerned them or that they had noticed throughout the entire session.

3 – RESULTS

3.1 RESULTS OF GAZE MEASUREMENT

In this paper, we report the results of gaze measurement and movement measurement.

(1) Experts

Part of the results of gaze measurement are shown in *Figure 7*. The circles in the photographs indicate the final gaze position at that point, and the lines show the gaze moving toward that point. From *Figure 8,* it can be seen

(1)Surface *(2)Back*

Figure 7: Eye-tracking results during planing (Experts)

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that the gaze is on the part where the two blades of the plane overlap. The gaze is concentrated on the blade of the plane on both the front and back sides.

As the planing progresses, it can be seen that the carpenter is moving the plane while checking the scraps. The flow of the gaze during planing is shown in *Figure 8.* When starting to plan, the carpenter checks the material and his feet before holding the plane. When the planing begins, the carpenter's eyes are on the plane, but as the planing begins, the carpenter's eyes begin to look at the direction of travel on the material. Planing After each planing, the carpenter visually and palpates the area that has been planed.

(3) Planing *(4)Finished*

Figure 8 Eye-tracking results during planing

(2) Inexperienced participants

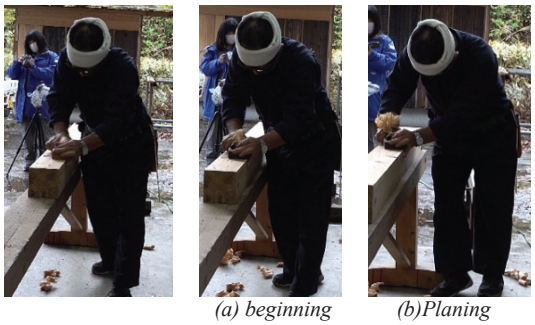
As shown in *Figure 9,* it was confirmed that Inexperienced participants tend to focus on where to hit with the hammer when adjusting the plane. If you adjust the plane by focusing on where to hit, it will be difficult to adjust while checking how much the plane blade moves with your own strength, and it will be difficult to make the adjustment you want.

In the first measurement, many subjects did not look at the wood,and if we include subjects who could not be measured, more than 28% of the gazes of 60% of subjects were directed outside the wood. However, data was collected from all subjects in the second measurement. In the second measurement, the gazes no longer wandered off the wood. There was a tendency for the gazes to be directed more toward the plane.

3.2 RESULTS OF MOTION TRACKING

(1) Experts

The results of the motion tracking are shown in *Figure 9*. The measurements confirmed that a) the hips were at right angles to the wood, b) the feet were secure, and c) the carpenter's hind legs were turned to the side and his legs were crossed when he retreated.



(a) beginning *(b)Planing*

(1) Hip Position. *(2) Check footing*

Figure 9: Posture and gaze state during planing as seen from motion measurements

(2) Inexperienced participants

The motion tracking of inexperienced participants showed a large degree of variation due to individual differences, making it difficult to grasp the trends. Some people were confused due to differences in dominant hands.*Figure11* shows an example of the motion tracking of a Inexperienced participants. In the first test, it was confirmed that a) the Inexperienced participants tried to look at the plane from directly above, so his back was at a right angle to the material and his hips were raised, b) he was constantly watching the movement of the plane, so his eyes were always on his hands, and c) he was trying to move with the plane by stretching out his dominant hand to hold the plane in place, and then moved his whole body backwards.

(1)1st time *(2)2nd time*

Figure 10 Posture when planing(for Inexperienced

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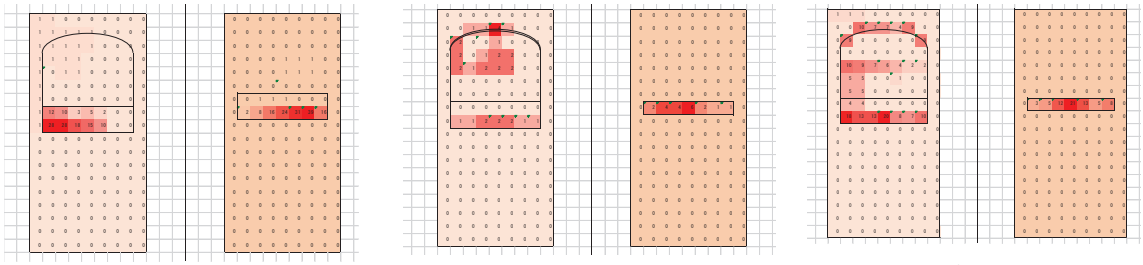
4- GAZE COMPARISON

4-1. GAZE COMPARISON

As shown *Figure 11*, Specialists workers do not look at the plane but look at the traveling direction, so the ratio of looking at the plane is concentrated in the range of 20 - 30%.(*Figure 12*) On the other hand, among the inexperienced participants, the variance was large at 30-80% in the first planing session (after general guidance) and smaller in the second planing session (after individual guidance), but the average percentage of workers looking at the plane increased. The reason for this was that he could not watch the first time because his posture was not stable. It is considered that the second time, by lowering the waist and pulling the plane, it became possible to see the plane diagonally from the traveling direction, not from directly above, and the dispersion of the line of sight decreased.(*Figure 13*)



(a)1st time *(b)2nd time*

(1) Expert *(2)Inexperienced participants*

Figure 11 Number of seconds spent watching the plane when adjusting it [s]

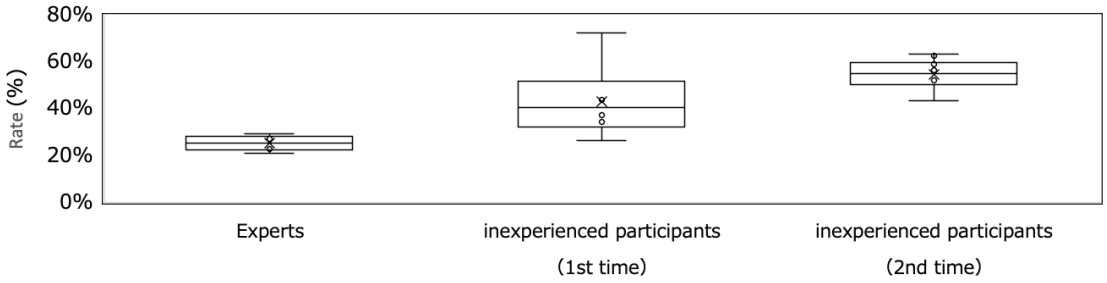
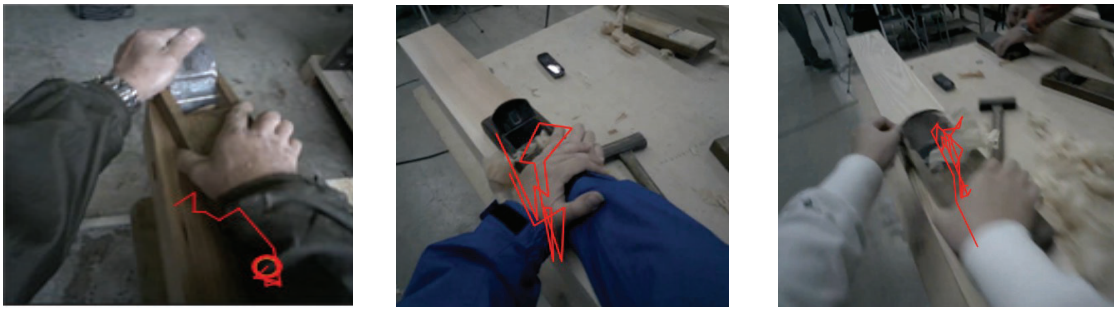


Figure 12 Rate of looking at the plane when planing



(1)1st time *(2)2nd time*

(1) Expert *(2)Inexperienced participants*

Figure 13 Result of eye tracking

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4-2. OPERATION COMPARISON

Figre 15 and *Figre 16* show comparison of the movements of an expert and an inexperienced participant during the first planing. While an expert holds his arms close to his body while planing, an inexperienced participant pulls the plane with his body while keeping his arms extended and fixed. After individual instruction, the inexperienced people received posture instruction during planing, and many of them showed improvement in their posture. Furthermore, the analysis of the movements showed that the experts put more force into their lower body and lower abdomen.

Figure 14 Actions of an expert and an inexperienced participant (first planing)

Figure 15 Angle of view (2nd planing)

5 –Analysis of proficiency

To analyze the proficiency of Inexperienced participants, we performed an analysis of the gaze of the skilled carpenter and the gaze of the inexperienced participant before and after individual instruction during adjustment of the plane, using a t-test (paired one-sample t-test, significance level 5%). From the analysis of the gaze measurement data during adjustment of the plane, two areas were set as the areas where the gaze of the skilled carpenter and the inexperienced participant was concentrated(*Figure 16*). Area A is the area where the skilled carpenter particularly focused on the cutting edge when adjusting the plane, and Area B is the area where the inexperienced participant focused on the place where the plane was struck during adjustment. The t-test results are shown in *Table 4.* The test results were t=|-9.43|>0.05, and no significant difference was observed between before and after individual instruction within the scope of this experiment.

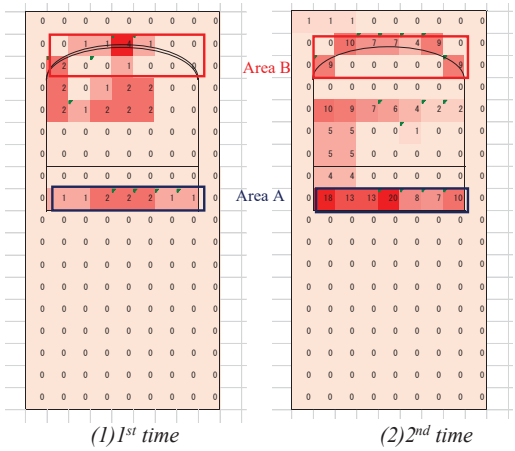

Figure 16 Area of t-test

Table 4 t-test results

	Area A		Area B	
	1st time	2nd time	1st time	2nd time
mean	16.738	34.543	34.353	21.842
variance	42.689	79.859	230.559	68.421
Observation	9	9	9	9
degree of freedom	8		8	
t	-9.434		3.032	
P(T<=t) one-sided test	6.543		0.008	
t-boundary value one-si	1.860		1.860	
P(T<=t) two-sided test	0.000		0.016	
t-boundary value two-si	2.306		2.306	

6 –CONCLUSIONS

This study employed gaze and motion tracking to visualize the 'planing' process. The findings are as follows:

1) When adjusting the plane, experienced carpenters tended to look at the cutting edge, while inexperienced carpenters tended to look at the place to strike.

2) When planing, the inexperienced carpenter's eyes were fixed on the plane, while the experienced carpenter's eyes moved to be ahead of the plane. In terms of motion, the experienced carpenter worked by pulling the plane to his body. On the other hand, in the first measurement, the inexperienced carpenter was confirmed to have stretched

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out his dominant hand to fix the plane in place and moved his whole body backwards in order to move with the plane. In the second measurement, the inexperienced carpenter began to look at the plane from slightly behind with his body turned half-way, his hips were facing parallel to the material and the position of his hips was lowered, his elbow was slightly bent to pull the plane to his arm, and he was confirmed to have moved while looking behind him.

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