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Investigation of Skills Training System Using TF-IDF for the Plasterer's Skeletal Data

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Abstract: artisans and athletes have the tacit knowledge, such as skills and tips that their bodies have learnt. These skills usually require a long apprenticeship. We thought the TF-IDF could be used to visualize tendency and frequency of mistakes made by beginners and investigated whether the TF-IDF could be used from data on past Sakan work.

Keywords: Embodied knowledge, skills training, learning support, TF-IDF

1. Introduction

Skilled artisans, artists, and athletes they have skills that are difficult or impossible to verbalize, such as techniques and knacks that the body has learnt. This is known as 'tacit knowledge' (Polanyi, 1966). Tacit knowledge is difficult to verbalize and must be discovered by the individual over a long period of training and experience.

An example of the plasterers with skills that include tacit knowledge, we discuss the traditional Japanese Skill called “Sakan.” Sakan plasterers use clay and white stucco to plastering walls and floors using a trowel. The beginners who learn Sakan struggle to master plastering operation. This is because the required Sakan technique depends on various factors, such as the characteristics of the material, the temperature and humidity of the workplace, physical condition, and a condition of finishing surface of wall to be achieved. Skilled plasterers can adjust by individual intuition; however, the beginners cannot adjust by one. The beginners need long training and experience to acquire this intuition.

Observation learning of artisans with tacit knowledge including Sakan plasterer using videos is sometimes used to get this intuition. However, it is difficult for beginners with little knowledge to grasp their improvement points by comparing their own videos with demonstration videos. In general, they grasp areas for improvement through advice from their instructors, but they may not be able to receive frequent advice due to a lack of instructors.

Therefore, this study investigated the requirements for analyzing the behavior and triggering support from the videos and daily reports of beginner Sakan plasterers who conducted observation learning and created a system based on the requirements. That is a feasibility study to confirm a learning method in which instructional information is superimposed on video viewing materials for beginners have a positive impact on self-modelling, targeting beginners who are thinking about grasping their improvement points through video viewing and who are in an environment in which they cannot expect active advice from supervisors.

The structure of this thesis is as follows. Chapter 2 clarifies the specific form of support we take and where we stand through relevant previous research and our work to date. Chapter 3 describes the learner's recently videos and daily reports, learning scenarios, and methods used in this research. Chapter 4 describes the basic design of support system and confirms from TF-IDF values that similar support can be provided based on past learner videos. Chapter 5 discusses the results. In Chapter 6, we summarize the study, conclude, and discuss future developments.

2. Related work and our study

It is an important learning method in learning a craft to seek solutions to improvement points that exist in one's work through self-awareness and training. However, conventional individual learning methods for Sakan are based on educational texts and videos having reference actions. This study aims at more individualized learning and provides a method different from existing prepared text- and video-based learning. The system selects improvement points from actual learner training videos, dynamically generates feedback, and provides it to the learner. We will consider methods that provide personalized learning indicators through sensory representations.

Self-modelling with video feedback is used to enhance motor learning; according to Kok et al. (2020), self-regulated video feedback without teacher instruction on movement skills has similar learning effects to traditional teacher instruction in physical education settings, and even also reported that self-regulation of feedback is positive for self-efficacy (self-efficacy) and perceived learning effectiveness. However, as reported by Rucci & Tomporowski (2010), it should be noted that providing only video feedback to learners without additional cues has little impact on skill acquisition. Therefore, in this study, video feedback is used for learner self-modelling and “Sports Onomatopoeia” is used as an additional cue for learning.

“Sports Onomatopoeia” is often used in Japanese sports to communicate to athletes the differences between subtle movements that are difficult to describe in humans in an ambiguous and intuitive way. The term “onomatopoeia” is used in Japan to encompass both “onomatopoeia” and “mimetic words.” Therefore, when “Sports Onomatopoeia” appears in a text after this, it is used in the sense that it encompasses both “Onomatopoeia” and “mimetic words.” According to Kikkawa (2013), “Sports Onomatopoeia” is reported to be used as a term to describe five aspects of movement: power, speed, persistence, timing, and rhythm. The term is reported to be used to describe the power, speed, sustainability, timing, and rhythm of movement. It is expected that “Sports Onomatopoeia” will contribute to learner awareness by being superimposed on scenes having points for improvement that are difficult for learners to notice. In addition, “Sports Onomatopoeia” is made to operate in a form that follows the movement that the learner should refer to in a scene that includes improvement points. It is expected that the movement itself and the nuance of the sports onomatopoeia will induce a change in the learner's movement, and as a result, the learner will be able to get out of the state of inadequate movement.

In a study using “Sports Onomatopoeia,” Gotoda et al. (2020) reported on a trial-and-error support system for learning high-load squats. (2020) reported on a system to support trial-and-error to learn high-load squats. In the report, a method of superimposing onomatopoeia on a video was used to make the learners aware of the post-load movements within a safe range, and “the group that received instruction tended to lose balance more easily. ”(i.e., onomatopoeia encouraged trial and error by the learners.) It has been reported that. The usefulness of adjusting the vocabulary used, font size and movement when superimposing onomatopoeia has also been reported by Gotoda et al. (2024).

Motion capture, which is often used for kinematic analysis of the human body in the field of sports science, is used to adapt “Sports Onomatopoeia” to video feedback. Motion capture is a system that measures the movement of the human body in three-dimensional space for many parts of the body, such as the eyes, ears, shoulders, hips, and elbows, and archives them along a timeline. Motion capture analyses the learner's body movements and checks the appearance of improvements in the learner's movements to determine when to superimpose “Sports Onomatopoeia.”

As a condition for improvement points during Sakan work, the differences between skilled and unskilled Sakan plasterers identified in the studies of Ooe et al (2020) and Takai et al (2016) are used as conditions.

According to Ooe et al (2020), the key point of the type of Sakan work movement by advanced practitioners is reported to be that “the lower body does not move horizontally or vertically in relation to the work surface during the plastering operation." Based on this, they also report that the two necessary indicators for intermediate and beginners are "fixation of the hips during the plastering operation" and "stabilization of the lower body during the plastering operation rather than fixation." In addition, Takai et al. (2016) report that the movements of skilled Sakan plasterers have conditions such as "shoulders not tilted" and "hips and knees within the width of both feet', whereas unskilled workers express movements such as "shoulders tilted" and "left shoulder deviating from the width of both feet."

From the research assumptions we have made so far, we will review the specific form and position of the support we will take. We will consider a support method that adds "Sports Onomatopoeia" as a learning cue to self-modeling learning using video feedback, which is often used for motor learning. In related work, "Sports Onomatopoeia" has been added to the learner's videos selectively by the researcher, or to all the error locations, to visualize the error behavior. However, in actual learning situations, feedback is not given to all errors that occur. This is because the learner's learning load is extremely high.

In this paper, we extracted some parts of the learner's work video that we wanted to focus on and visualized the error behavior for those parts to support learning. We analyzed the learner's video using motion capture and measured the occurrence of errors by comparing the obtained skeleton with the improvement points in Sakan work that have been found so far. We assess whether the measured improvement points can be automatically ranked in terms of the importance of a certain error behavior in each action segment by using Term Frequency-Inverse Document Frequency (TF-IDF). Based on this ranking, we will examine a method to automatically provide visualization and support for the action segment.

3. Scenario or Method

In our research, for example, given a minute work video, we aim to superimpose onomatopoeia on ten second segment of a video and make the viewer focus on that segment. There are two problems to be solved for this purpose: the first is the judgment of the missed behavior, and the second is the assignment of metadata to the missed behavior intervals.

The first problem is to find the missed actions. It is very stressful for the learner to look back at all their plastering and reflect on what mistakes were made at what points. It would be especially useful for learners to know what kind of mistakes they make and how often they make them, to reduce their learning load and to reflect on their skills. Therefore, in this paper, we focus on the judgment of error behavior.

Second, we consider the second method of adding metadata to the segments of the error behavior, which is to superimpose Sports Onomatopoeia on specific segments of a video to make the learner focus on own error behavior. Therefore, when the system helps the learner, it is essential to keep the time points where the support is needed. Although we do not deal with this issue in detail in this paper, we intend to achieve this by keeping the number of frames in a video at which a mistake is made and what kind of mistake is made when judging a missed action.

Based on the actual Sakan learner's video and daily reports, an ideal learning model is defined and the requirements for the system's support are defined. From the requirements, we consider the adaptation of TF-IDF to videos. In addition, we describe the conditions for adapting TF-IDF to videos.

3.1 Sakan Learner's Video and Daily Report

The learners considered in this study are individual learners who want to understand their own areas for improvement through video viewing, but who are beginners in an environment where active advice from an instructor is not possible. To consider support for them, it is necessary to understand the learning model who have conducted instructor-guided observational learning of Sakan. To this end, video and daily reports taken at Sakan training center in Hokkaido, Japan, were utilized.

The learner who was the subject of the data used in this paper was a graduate student at Shibaura University (hereafter referred to as Learner A). The data are from a video and a daily report of a Sakan training. Learner A had a little knowledge of Sakan , but had never actually plastered before. Learner A studied for ten days (total number of days excluding Saturdays and Sundays), workingsix hours a day, including attending lectures. Recorded a video of their own Sakan skills, as well as a daily report at the end of each study day.

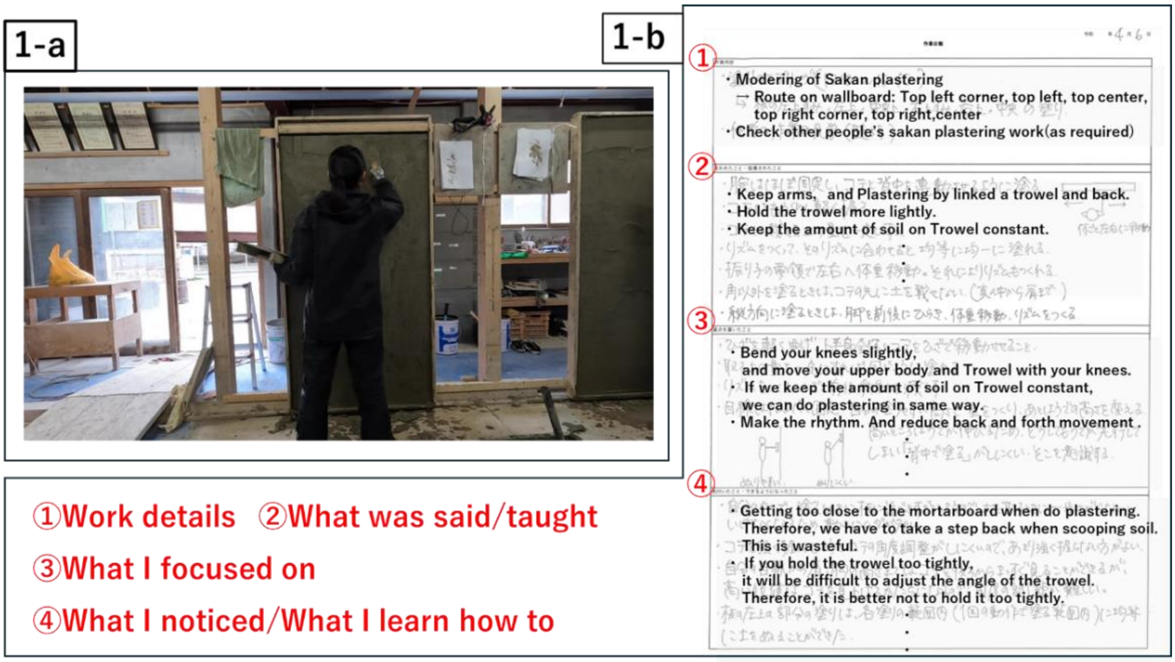


Figure1 Examples of recorded videos and daily reports used for research.

Figure 1 shows an example of a video and daily reports of the learners. 1-a is a screenshot of the videos of a training session at Sakan vocational training school in Hokkaido, Japan, which is used for beginner training. 1-a is a screenshot of a video of a training session called “Nurikabe Training” at a Sakan training school in Hokkaido. “Nurikabe Training” uses a teaching method whereby the trainee learns the plastering operation by using video footage of the model plastering operation. This method is characterized by the fact that a video model is the same for all trainees, so that there is no variation in the training. The final goal of the wall training at the vocational training school is to apply soil to a 900 mm x 1800 mm sheet of plywood for concrete formwork and to level it within three minutes each time, and to complete twenty times within one hour. 1-b is an example of a daily report made by the learners. The learners are listed based on (1) Work details (2) What was said / taught (3) What I focused on (4) What I noticed / what I learn how to.

3.2 Ideal growth model for Sakan learners.

In order to support skill acquisition through video viewing, it is first necessary to clarify the ideal skill acquisition process for beginners: Gotoda et al (2024) reported that the development of the Sakan beginner “involves a series of steps in which the body learns to do what is being taught consciously and unconsciously, and when the body is able to do it unconsciously, it moves on to the next step, approaching the end point, the final day.” The plasterers repeatedly moves on to the next step when he can do so subconsciously, and then takes steps to get closer to the final day, which is the point of conclusion.’ Figure 2 summarizes and defines the development of Sakan beginners who have been trained to paint walls, with the reported content in mind. The items are defined based on the learning process in the social learning theory proposed by Bandura.

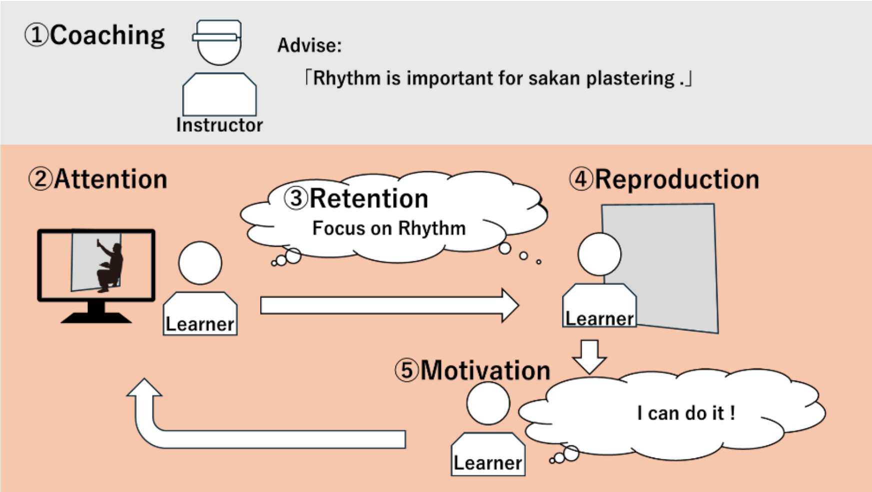


Figure2 Growth model for Sakan

The coaching is a step in which the instructor gives advice to the learner. The instructor points out the learner's mistakes and deficiencies from an objective standpoint, and the learner uses the points as clues for further learning. Steps (2) to (5) are the learners' learning cycle. The learner directs attention to (2) the object of observation using the advice as a cue, and (3) retains the content of the action. The learner then (3) retains the content of the behavior and (4) imitates the behavior of the target. As a result of imitation, the learner recognizes own skill improvement and (5) motivation increases.

In this cycle, the instructor's advice plays an important role. In learning with less instructor intervention, the opportunity to receive pointers is reduced compared to traditional learning. It can also be said to mean that learners have fewer opportunities to reflect on their own mistakes and shortcomings. When opportunities to reflect on errors and deficiencies decrease, learners may lose their direction in the middle of the learning cycle, and their learning may stagnate.

3.3 Forms of support needed.

As mentioned in Chapter 2, it is becomes clear that there are certain conditions that a beginner in Sakan must overcome to become an intermediate or advanced plasterers. For the learner, the goal of learning is to achieve all these conditions.

How should the learning support system impose the learner to achieve these conditions? It is not usual in learning to present the learner with all the points for improvement in situations where the conditions are not fulfilled, i.e., where improvement is needed. This is because too many points for improvement can confuse the learner. Inevitably, limited improvements are offered to the learner. In normal learning, this is the primary domain of the instructor, who uses the structured learning process and own experience to select the improvements the learner needs at the current stage and to provide the learner with the training necessary to make these improvements. This suggests that in learning with little instructor intervention, the learning system, like the instructor, needs to provide the learner with learning support that focuses on the improvements that the learner needs to make at the current stage.

To provide learners with learning support that focuses on the improvements they need at the current stage; the following two points need to be considered.

Q1. how to select the advice

Q2. When to present the advice.

This study looked at two ways to solve the problem. A1. select the advice by TF-IDF

A2. show the time of the strongest error for the selected error.

TF-IDF is a method used in natural language processing and is a statistical measure of the importance of words in a document. Specifically, the term frequency (TF), which shows how often a certain word appears in a certain document, is multiplied by the inverse document frequency (IDF), which shows how infrequently a document containing a certain word exists among all documents. IDF), which shows how infrequently a document having a certain word exists among all documents.

It is necessary to select elements from a video that correspond to those included in the TF-IDF formula in natural language processing to evaluate improvements that appear in a video using TF-IDF. The TF-IDF formula in natural language processing is shown in equation (1)

$$tf\text{-}idf(t,d) = tf(t,d) * idf(t) = \frac{\#\, of\ t\ in\ d}{\#\, d} * \frac{\#\, D}{\#\, \{d \in D | t \in d\}} \tag{1}$$

TF-IDF is a method for calculating the importance of a word in a document in natural language, based on the frequency of its occurrence in a document and the frequency of its occurrence in multiple documents. If this works as expected in video processing, the system should be able to select more characteristic improvements, such as improvements that occur more frequently in the entire video or specific improvements that occur more frequently in a certain video segment.

For a beginner learner to recognize which actions are incorrect and to perform introspection, it is first necessary to recognize the actions that deviate from the correct actions. Therefore, the learner is asked to view the time points where the behavior he/she wants to improve deviates from the correct behavior.

3.4 Ranking of misbehavior by TF-IDF

In the previous section, it was assumed that the TF-IDF is used to decide the advice to be given, and the interval of the strongest error is presented as the timing of the advice. In this section, we summarize how the TF-IDF is applied to diagnose the tendency and frequency of error behavior by the training system to adapt it to Sakan training.

First, the method to decide the tendency of error behavior is based on the comparison of TF-IDF values. If the TF-IDF value is large, it shows that the road errors are characteristic for that time interval.

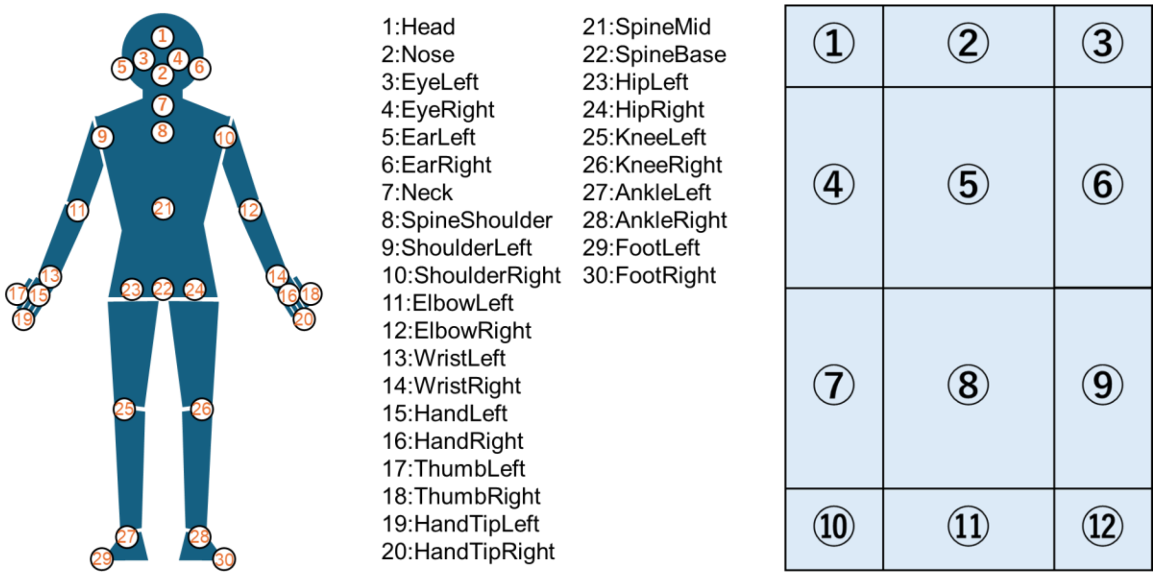
Next, the frequency of the behavior can be decided by the simple number of occurrences of errors in each time interval. The frequency throughout the day can be decided by a simple comparison of the number of occurrences of the tendency to make a error in a certain time interval, aggregated for one day and classified by the behavior of making a error.

In our study, we define the most frequent error behaviors throughout the day as those that should be corrected in the day's training videos. In addition, we decide the interval in which the TF-IDF value of the error behavior to be corrected is the highest in a certain time interval as the interval to be reviewed and superimpose sports onomatopoeia on this interval and provide it to the learner.

4. Consideration of TF-IDF

4.1 Classification of skeletons and working areas of Sakan to be used

From the previous chapter, it was decided that TF-IDF would be used to select the advice and set the timing for advice to be generated. Therefore, as the first step of the TF-IDF process, the motion capture used and the skeletons that can be obtained are first summarized, and then the plastering movements of Sakan are classified based on which part of the wall surface is being plastered.



a) Skeleton data correspondence diagram b) Work area distribution in Sakan

Figure 3. Skeletons and classification of work areas.

In this paper, “Vision Pose” is used as the motion capture software. “Vision Pose” is a kind of optical motion capture software that uses a posture estimation AI engine that can analyze human skeletons and postures without markers. Since it does not require an infrared intensity sensor, it can capture the skeleton both indoors and outdoors with a general-purpose webcam. Figure 3 a) shows the thirty skeletal coordinates that can be obtained with “Vision Pose.” In “Vision Pose,” the captured skeletal coordinates can be downloaded to a PC in CSV format.

In this paper, the plastering operation is classified into 12 categories as shown in Figure 3-b. Roughly speaking, when working in areas (1), (2), (3), (4), (5) and (6), the operator is in a standing position, and when working in areas (7), (8), (9), (10), (11) and (12), the learner is in a squatting position.

Basically, the plastering operation is performed in the order of OUT-IN (paint outwards from the wall and then turn around to shoot at the wall) in the outer periphery of the work surface {(1), (2), (3), (4), (6), (7), (9), (10), (11), (12)}, while inside the work surface {(5), (7)}, the plastering operation is performed from bottom to top and then turn around from top to bottom.

The conditional equation that checks the missed action decides whether the action passes or fails (presence or absence of an error). TF-IDF is performed by keeping the number of frames in which an error is determined to have occurred by the conditional equation and replacing it with the number of word occurrences in TF-IDF.

4.2 Conditional expressions to determine actions to be improved

To use TF-IDF in motion analysis, it is necessary to fit the elements of motion analysis into the formula. Table 1 summarizes the meaning of each denominator in the TF-IDF formula as it is used in natural language processing and maps a video to it.

Table1 Denominator of each numerator in the TF-IDF formula

Attempts	NLP	This system
# of t in d	Number of occurrences of word t	Number of frames of appearance of action t that need improvement
# d	Number of words in document d	Total number of frames in video d
# D	Number of all documents	Number of all videos
# { d ∊ D | t ∊ d }	Number of documents having the word t	Number of videos having the action t

・Wobble of plastering

As mentioned in the premise study, it is necessary for Sakan beginners to practice a plastering technique that does not cause their knees to deviate from their heels to improve their technique. Therefore, in this study, the Sakan beginner’s knees were checked for deviation from the heel area using condition equation (2), and if deviation was identified, it was saved as an area for improvement.

$$\text{(Both)Heel\_x} < \text{Knee\_x} \tag{2}$$

・Rhythm of plastering

Sakan training involves periodic movements synchronized with wall plastering appear.

In Sakan schools, beginners are trained to memorize this rhythm by having the instructor hold the beginner's shoulders and shake them, so that the body learns the ideal periodic movements. In this case, the ratio of the distance to and from the instructor is approximately 1:1. In the present study, the learner's rhythmic movements are monitored using the conditional equation (3) to see if they are approximately 1:1, and if deviations are detected, the rhythm is considered to have been broken in that session.

$$\text{(Target is shoulder) Amount of movement OUT side} : \text{Amount of movement IN side} = 1 : 1\ (\pm 0.1) \tag{3}$$

4.3 Assumptions for the video to be used.

We used the 10th day of training videos from the Sakan Training School. The reason for this is that the state is one in which the technique has moved from a state in which it has not yet been settled to a state in which it has been settled to some extent, and in which errors in the training have decreased.

The movements targeted in this paper is those in areas (2), (4), (5) and (6). This is because the movements targeted by Ooe et al. (2020) and Takai et al. (2016) are standing movements, and the movements at the corners (1) and (3) are slightly different from normal plastering movements and do not fit the conditional equation used in this paper.

One process in Sakan is defined as the consumption of the wall material on the trowel plate, and one trial is defined as “the process from the contact of the trowel with the wall surface to the release of the trowel.” A total of ten processes were manually extracted from the tenth day’s training videos. A total of fifty-four trials were obtained and evaluated.

4.4 Experimental application of TF-IDF to historical video

Table 2 summarizes some of the results of the TF-IDF for two errors that occur to appear in beginners.

The table shows the TF-IDF values for the two errors. The red-colored areas are those where the TF-IDF value exceeded the threshold value, showing that improvement is needed. In this case, the TF-IDF threshold is set to zero point six. The significant digits are set to five decimal places.

Table2 summarizing the TF-IDF.

No.	Parameters	TF	IDF	TF-IDF
1-1	Knee > heel	1.00000	1.00000	1.00000
	Rhythm Disorder	0.00000	1.55962	0.00000
1-2	Knee > heel	1.00000		1.00000
	Rhythm Disorder	0.44068		0.68729
1-3	Knee > heel	1.00000		1.00000
	Rhythm Disorder	0.34328		0.53538
1-4	Knee > heel	0.96296		0.96296
	Rhythm Disorder	0.00000		0.00000
1-5	Knee > heel	1.00000		1.00000
	Rhythm Disorder	0.28889		0.45056
1-6	Knee > heel	0.45161		0.45161
	Rhythm Disorder	0.46667		0.72783
1-7	Knee > heel	0.01639		0.01639
	Rhythm Disorder	0.00000		0.00000

5. Consideration

From the experiment of adapting the TF-IDF in Chapter four to the past Sakan video, it was confirmed that the TF-IDF showed the strongly expressed points of two errors that tended to appear in beginners of Sakan. For the error of knee deviation from the heel, it was confirmed that the TF-IDF value was nearly equal to (or even equal to) one in certain instances. In these instances, it was verified that the learner's foot opening was often narrow. This is a correct value in regard to the reduction in stability of the plastering. On the other hand, due to the height characteristics of the learners, there were instances when the foot opening became narrower when working at a high height on the work surface. This suggests the need for future measurements that take into account the height characteristics of the learner.

The TF-IDF have the potential to flexible in deciding the learning target than the conventional educational method. In this paper, only two conditionals were used. In the future, more conditionals will be added to detect more error behaviors. This will enable to support learning according to the learner's errors.

For instructors, the results of the present study will be useful in focusing learners on the areas where more errors occur by providing an indicator of which section shows more error behaviors that they want to focus on. For the learner, the system is expected to provide a steppingstone to more effective learning by helping the learner to find own correction points, something that has been difficult to do in traditional individual learning. For educational technologists, it will help them to consider the possibility of adapting the system to similar technical areas of education.

6. Summary and Conclusion

Summary of this study. This study focused on an approach that has not been used in previous Sakan research, which is to use a system to automatically select the error behavior suggestions to be provided to the learner. We also conducted an adaptation experiment on past Sakan videos to confirm how the TF-IDF values are displayed.

Conclusion of this study. Experiments using the TF-IDF on actual Sakan video showed that the trend and frequency of the TF-IDF values are showed in the form of TF-IDF values. This suggests the possibility of using TF-IDF values to rank misbehaviors to decide support contents.

In future research. First, it will be important to increase the number of conditionals. By increasing the number of conditionals, it will be possible to provide more detailed support to learners. Second, automatic extraction of working intervals is necessary for the system to be used in actual training schools. Third, it is essential to consider which words should be used among the sports onomatopoeias in order to adapt the system to the learner's sensibilities.

In addition, the proposed system is intended to be developed as an individually adaptive Sakan learning material. Therefore, it is necessary to clarify how the system contributes to learning outcomes. In the future, we will compare learning by the system with learning by a human instructor. Comparisons will be made in terms of the percentage of reduction in error intervals and improvement in work speed. This will allow us to evaluate the effectiveness of the system for learning at this stage and to identify further issues to be addressed.

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