Fundamental Study for Verbalization of Embodied Expertise based on Pattern Recognition

Hiroki Hojo, Nozomi Nomachi, Yutaro Tomoto, Tsuyoshi Nakamura, Masayoshi Kanoh and Koji Yamada

***Abstract*— Embodied expertise, which expresses skills of experts, is a kind of tacit knowledge that is difficult to transfer from one person to another by writing it down or verbalizing it. The aim of our study is to translate embodied expertise into explicit knowledge, i.e. onomatopoeias. We call the onomatopoeias "embodied expertise onomatopoeias", which can enable people to understand the skills intuitively and easily. Acquiring embodied expertise onomatopoeias is considered as a problem of pattern recognition. Our study focused on the skills of Japanese penmanship, Pen Shodo, which is Japanese calligraphy using a pen, to translate tacit knowledge into onomatopoeias and investigated the possibility of constructing a training system for these skills.**

I. Introduction

SKILLS of expert sportspeople, dancers, or musicians are known as embodied expertise, which is a kind of tacit knowledge [1][2]. For example, after mastering bicycle riding, people never forget how to ride and operate bicycles easily. This implies that people have embodied expertise to ride a bicycle. However, embodied expertise is difficult to transfer from one person to another by writing it down or verbalizing it. You can understand the difficulty if you imagine explaining how to swing a baseball bat to other people by using only linguistic representations. That means unclear correspondence between embodied expertise and explicit knowledge like linguistic representation.

On the other hand, onomatopoeias are widely used in Japanese to express sounds, appearances, motions, or voices of things. Onomatopoeias, which are echoic, imitative, or mimetic words, are a basic part of Japanese language and are used to supplement the shortage of verbs compared with other languages. For example, English contains are a lot of verbs to describe walking styles, such as plod, stroll, strut, and swagger. Meanwhile, Japanese contains only one, aruku. In general, most Japanese onomatopoeias can be explained by the concept of sound symbolism, which is the idea that phonemes carry meaning in and of themselves regardless of the language, so onomatopoeias are good for describing ones' intuitive, perceptive, and ambiguous feelings [3]. Even if "onomatopoeia" is new word to you, you will have frequently seen and found onomatopoeias in comic books as shown in Fig. 1.

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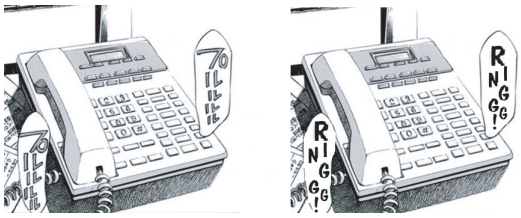

Shuho Sato, Give My Regards to Black Jack, Manga on Web, http://mangaonweb.com

Fig. 1. Onomatopoeia examples in a comic book

Japanese speakers often use onomatopoeias in daily speech because onomatopoeias can enable people to communicate easily and intuitively. When playing sports, dancing, or playing musical instruments, people use onomatopoeias to express their skills because they are used to using onomatopoeias. Thus, people can share their embodied expertise by using onomatopoeias.

The aim of our study is to translate embodied expertise into explicit knowledge, i.e. onomatopoeias. We call the onomatopoeias that express embodied expertise "embodied expertise onomatopoeias", which can enable people to understand the embodied expertise intuitively. However, translating embodied expertise into the embodied expertise onomatopoeias presents some problems. One of the main problems is the ambiguity of onomatopoeias. The effect or meaning of an onomatopoeic word relies on the context in which the word is used. For example, even if an onomatopoeic word is used in different sports, the word may not always express the same action. In other words, by restricting the contexts or the situations in which onomatopoeias are used, they may possibly be used effectively. An onomatopoeia is easy and intuitive to understand for the people who usually use it. Moreover, it is very similar to a fuzzy number since it does not refer to one single value but is rather connected to set of possible values. If we can establish how to use onomatopoeias, they may be a useful conceptual tool like fuzzy numbers.

Translation into embodied expertise onomatopoeias could be considered as correspondence between skillful actions and onomatopoeic words. In our study, the correspondence to be clarified is dealt with as a pattern recognition task. There are a lot of actions and onomatopoeic words that we should investigate. Among people, especially Japanese speakers, onomatopoeias are as easy and intuitive to understand as fuzzy numbers. Onomatopoeias help people to communicate. Our study is an attempt to clarify the correspondence be-

tween skillful actions and onomatopoeic words.

The correspondence is also expected to be useful to evaluate a robot's behaviors or motions. Ito et al. [4] proposed and developed a method to design robot motions using onomatopoeias. The results of our study can help this design. Therefore, this study can contribute to the development of the research field of human robot interaction (HRI).

For skillful actions to be translated into onomatopoeic words, we chose and adopted the actions of Japanese penmanship, Pen Shodo, using a pen. Japanese calligraphy using a brush, Shodo, is a popular art form in Japan. Pen Shodo is a similar art form, and improvement of Pen Shodo skills is useful for neat handwriting in business or daily life. Pen-writing skills are composed of several writing features. The important ones are the pen pressure that a writer puts on his/her pen and pen speed at which he/she writes. These two features greatly affect the appearance of Kanji characters written with a pen as well as Kanji characters written with a brush in traditional Shodo.

In this paper, we investigated the correspondence between the writing features and onomatopoeic words. The investigation results could provide fundamental knowledge to develop a training tool for Pen Shodo.

II. Related works

Other researchers have investigated ways to verbalize or evaluate embodied expertise. Tanaka et al [5] introduced Measurement of Prosody Recognition (MPR) to evaluate the skills of simultaneous interpreters of Japanese sign language. Kobashi et al. [6] focused on the skills of playing the cello. They investigated an Abductive Logic Programming (ALP) framework to find appropriate hypotheses to explain both professional- and amateur-level performances. Meanwhile, some researchers have studied the modeling of sports such like golf and baseball [7]–[11].

Also, some researchers have attempted to utilize onomatopoeias for engineering. Yoshino et al. [12] proposed and reported that differences in onomatopoeias associated with real and imitation metals can be used in metal texture design to create imitation materials that look and feel more like real materials. Doizaki et al. [13] applied onomatopoeias to a recommendation system for online shopping. Hashimoto et al. [14] developed an e-learning system for Japanese onomatopoeic expressions. Ueda et al. [15] proposed and provided a system that supports communication between Japanese patients and foreign doctors by applying an onomatopoeia evaluation system to medical use.

The abovementioned studies regarding onomatopoeias dealt with few topics related to human motions, skillful actions, and so on. Our study will help to bridge the gap between the studies related to embodied expertise and onomatopoeias.

III. Proposed model

Pen Shodo learners usually look at the characters written by Pen Shodo experts and improve their skills to write beautiful characters similar to those of the experts. As learners progress, they have to repeat writing characters in trial-and-error fashion to detect the differences between their own written characters and those of the experts. Rough differences in character appearance are easy to detect, but detailed differences are not. The experts can tell the learners how to handle a pen to write a beautiful character, but the experts are not always there to give these instructions.

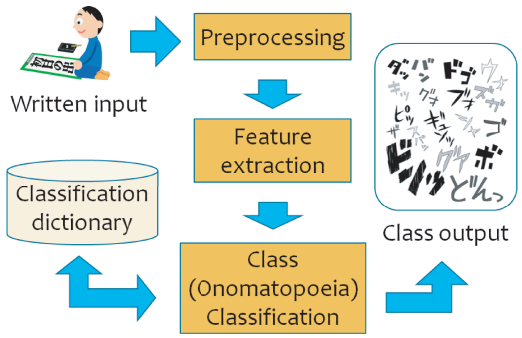

Fig. 2. Proposed model to verbalize writing-skill features

Linewidth of character strokes or pen-ink shades on a sheet of paper are important factors that affect aesthetics of characters in Pen Shodo. Dynamics of pen operation determine the linewidth of character strokes or the pen-ink shades. The learners attempt to watch the dynamics of experts' pen-writing operation to learn how to write beautiful characters. However, it is tough for them to recognize the time fluctuation of pen pressure and pen speed precisely. In this paper, the data verbalized by embodied expertise onomatopoeias are writing-skill features, i.e. pen pressure and pen speed. The embodied expertise onomatopoeias can teach the learners the writing skills relevant to pen pressure and pen speed.

Our study deals with pattern recognition to verbalize the writing-skill features. Fig. 2 illustrates the flow of our proposed system. As illustrated in Fig. 2, the system is composed of preprocessing, feature extraction, and classification as well as a general pattern recognition system. A Pen Shodo learner writes a character, and the time series data of his/her writing trajectory are inputted to the system. The preprocessing divides the time series data into all strokes that make up the character. The feature extraction then calculates pen pressure and pen speed for each stroke. The classification classifies the pen pressure and the pen speed into classes of embodied expertise onomatopoeias. The system outputs an onomatopoeic-word list in accordance with the order of the strokes.

If both the learner and the expert write the same character using the system, the learner can confirm and understand the difference in the onomatopoeic-word lists the system outputs. Learners who are familiar with onomatopoeias are expected to be able to recognize the difference intuitively and improve their writing skills effectively.

TABLE I

ONOMATOPOETIC WORDS

Alphabetical notation	Phoneme of Japanese	Japanese Kana (syllabic Japanese script)
su	/su/	??
su’	/suQ/	????
zu’	/zuQ/	????
sû’	/suHQ/	???[??
shu’	/sjuQ/	??????

IV. STATISTICAL INVESTIGATION

To construct the training system illustrated in Fig. 2, an appropriate classification dictionary of embodied expertise onomatopoeias needs to be prepared. The ambiguity of an onomatopoeic word relies on the context or the locality in which the word is used. For example, the sound of a clock is tick-tock in English, but it is katchin katchin in Japanese. In addition to this, multiple onomatopoeic words sometime express the same sound, motion, and so on. Thus, it is no wonder that several onomatopoeic words express the same or similar pen pressure or pen speed. In this case, such onomatopoeic words do not need to be classified or distinguished. It is more appropriate to unify the onomatopoeic words into a class that includes the onomatopoeic words to express the same or similar pen pressure or pen speed. This is useful for distinguishing between classes.

To construct a classification dictionary of the classes, we investigated the similarity among onomatopoeic words related to pen-writing. This paper chose five simple onomatopoeic words shown in Tab. I: “su(/su/)”, “su’(/suQ/)”, “zu’(/zuQ/)”, “sû’(/suHQ/)”, and “shu’(/sjuQ/)”. These words are familiar to Japanese speakers and are often used to describe handling a pen. Each word consists of one syllable in Japanese that has one or more of the following sounds: resonant (unvoiced sound), geminate consonant, sonant (dull sound), long sound, and contracted sound. The words are compared to explore and clarify some effects of the five sounds for pen pressure and pen speed.

TABLE II

AVERAGE VALUE μ AND STANDARD DEVIATION σ OF PEN PRESSURE

	μ	σ
su’ (/suQ/)	0.601	0.096
su (/su/)	0.627	0.130
zu’ (/zuQ/)	0.804	0.104
sû’ (/suHQ/)	0.605	0.132
shu’ (/sjuQ/)	0.612	0.145

A. Data Acquisition

Each subject imagined the meaning of one of the onomatopoeic words shown in Tab. I, and he/she then drew a horizontal line in accordance with it. The ten subjects were all in their twenties (nine men and one woman) and right-handed. They did the operation 10 times for every onomatopoeic word for the investigation. They operated a stylus pen and a pen tablet, Wacom Intuos4 Pen Tablet. The line was drawn from left to right. A (x, y)-coordinate and a value of pen pressure were sampled every 60 msec. Fig. 3 shows the actual conditions of the experiment. We adopted the horizontal line for the investigation since it is a basic element of a Japanese character. Each Japanese character is composed of a combination of several strokes, and a horizontal line is one of the standard strokes.

TABLE III

AVERAGE VALUE μ AND STANDARD DEVIATION σ OF PEN SPEED (PIXEL/S)

	μ	σ
su’ (/suQ/)	76.835	24.966
su (/su/)	54.223	18.536
zu’ (/zuQ/)	42.478	16.081
sû’ (/suHQ/)	18.618	33.073
shu’ (/sjuQ/)	97.840	49.752

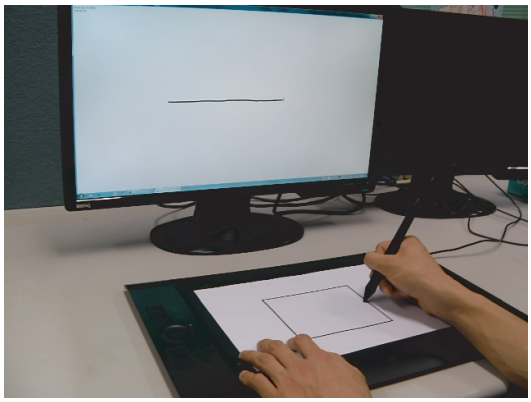

Fig. 3. Actual experiment conditions

We calculated the average value of pen pressure and pen speed for each line drawn. A total 500 samples (5 onomatopoetic words $\times$ 10 subjects $\times$ 10 trials) were collected for both the average pen pressure and the pen speed. The pen pressure is normalized to the range [0,1]. Tables II and III list the average value of the pen pressure and the pen speed calculated by using all the samples for each onomatopoetic word.

B. Clustering based on Statistical Analysis

We conducted a statistical analysis. We used Tukey’s method, which is a single-step multiple comparison procedure and statistical test. In our study, the null hypothesis is rejected if a p-value is found to be less than the significance threshold $\alpha' = 0.005$, where the threshold is calculated using Sidak correction. The results of the test (p-values) are listed in Tables IV and V.

As you can see from p-values of the average pen pressure in Tab. IV, some p-values are less than $\alpha' = 0.005$ between “zu’(/zuQ/)” and the others. Hence, this suggests that the presence of the sonant (/z/) affected the strength of the pen pressure.

TABLE IV

RESULTS OF STATISTICAL TEST ON AVERAGE PEN PRESSURE (P VALUES)

	su' (/suQ/)	su (/su/)	zu' (/zuQ/)	sû' (/suHQ/)
su (/su/)	0.5626			
zu' (/zuQ/)	0.0000**	0.0000**		
sû' (/suHQ/)	0.9996	0.6925	0.0000**	
shu' (/sjuQ/)	0.9746	0.8977	0.0000**	0.9946

TABLE V

RESULTS OF STATISTICAL TEST ON AVERAGE PEN SPEED (P VALUES)

	su' (/suQ/)	su (/su/)	zu'(/zuQ/)	sû' (/suHQ/)
su (/su/)	0.0000**			
zu'(/zuQ/)	0.0000**	0.0300		
sû' (/suHQ/)	0.0000**	0.9703	0.1500	
shu' (/sjuQ/)	0.0000**	0.0000**	0.0000**	0.0000**

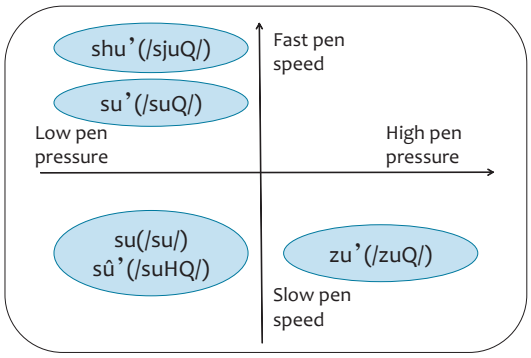

Fig. 4. Clustering based on significant differences

On the other hand, in respect to p-values of the average pen speed shown in Tab. V, there are significant differences between "su'(/suQ/)" and the others. Addition to this, there are also significant differences between "shu'(/sjuQ/)" and the others. "su'(/suQ/)" has /Q/, but this cannot sufficiently explain why the presence of /Q/ affected the pen speed, because other words also have /Q/. Allowing for "zu'(/zuQ/)" and sû' (/suHQ/) that have the combinations /z/+/Q/ and /H/+/Q/, the single /Q/ might have affected the pen speed. In addition to this, "shu'(/sjuQ/)" has the combination /Q/+/j/, which also might have affected the pen speed.

The above consideration and the order relationships are roughly summarized in Fig. 4. As illustrated in Fig. 4, four classes of the onomatopoeic words are constructed by considering their significant differences.

V. MULTI-CLASS CLASSIFICATION

The experiment involved using SVM to classify the five classes: "su' (/suQ/)", "shu' (/sjuQ/)", "su (/su/)", "sû' (/suHQ/)", and "zu'(/zuQ/)". The experiment is multi-class classification, and a one-versus-one classifier were used. C-SVM with the Gaussian kernel ($C = 5, \sigma = 0.2$) were used for the classification among five words by using both pen pressure and pen speed. One-hundred samples (10 subjects $\times$ 10 times) regarding pen pressure and pen speed were acquired for each onomatopoeic word. Half the samples for each class were randomly selected and used for the multi-class SVM classifier. The rest were used for test data. For the examination, 50 trials were done, and the average classification rates are shown in Tab. VI.

As shown in Tab. VI, the classification rate of zu'(/zuQ/) is over 75%, which is distinctly higher than those of other classes. Thus, the presence of the sonant (/z/) may possibly have affected the strength of the pen as well as argued in section IV-B. The classification rates of other classes are over chance level 20%, but these are not high enough to distinguish between them.

The words in the classes consist of one syllable in Japanese that has one or more of the following sounds: resonant (unvoiced sound), geminate consonant, sonant (dull sound), long sound, and contracted sound. It is considered that the presence of the sound influenced the classification rate. The writing-skill features of pen pressure and pen speed are somewhat related to the sounds of the words. The presence of the sonant /z/ is likely to have a particularly strong relationship with strength of pen pressure.

VI. CONCLUSIONS

We proposed verbalizing embodied expertise and investigated the correspondence between writing features and onomatopoetic words. The results of the multi-class classifier suggest that explicit discrimination is difficult for sounds other than "zu(/zu/)". A rigid system of classification is not suitable for the correspondence. Meanwhile, the results of the statistical test show many significant differences among onomatopoetic words, except between "su(/su/)" and "sû'(/suHQ/)". This implies that the writing features, i.e. average values of the pen pressure and the pen speed, could correspond to each onomatopoetic word. Thus, fuzzy fitness or likelihood, which can express ambiguity or uncertainty, would be suitable to construct the correspondence between writing features and onomatopoetic words.

On the other hand, some problems remain. First, the experiment used only five onomatopoeic words. There are many onomatopoeic words related to writing skills, so other words should be investigated. Second, other features of writing

TABLE VI

CLASSIFICATION RESULTS BETWEEN FIVE CLASSES

	su' (/suQ/)	shu' (/sjuQ/)	su (/su/)	sû' (/suHQ/)	zu'(/zuQ/)
one-vs-one	0.4540	0.4520	0.2948	0.3040	0.7588

skills need to be investigated. This study focused on pen pressure and pen speed, but there are other features of writing skills, i.e. pen inclination or stroke length. Finally, there exist individual variations regarding correspondence between writing skills and onomatopoeias. The experiment employed ten subjects and attempted to clarify the generalities or universalities of correspondence between writing skills and onomatopoeic words. It is considered that the ambiguity of onomatopoeic words partially depends on the individual variations, i.e. how familiar someone is with onomatopoeias, how skillful someone is with a pen, and so on. Considering the individual variations could make the system a more useful tool for Pen Shodo learners. It will also be interesting to investigate the correspondence regarding non-Japanese speakers. In the near future, we will address these problems and provide a practical system.

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