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Classification of Writing-Skill Features using Embodied Expertise Onomatopoeias

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***Abstract*— Embodied expertise, which expresses skills of experts, is a kind of tacit knowledge that is difficult to transfer to another person by means of 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 could facilitate people to intuitively and easily understand the skills. Acquiring "embodied expertise onomatopoeias" is considered as a problem of pattern recognition. Our study adopted a skill of Japanese penmanship "Pen Shodo" which is Japanese calligraphy using pen to be translated to onomatopoeias, and investigated a possibility to construct a classification system for the skill.**

I. Introduction

SKILLS of experts in sports, dancing or musical instruments performance are known as embodied expertise which is a kind of tacit knowledge [1][2]. For another example, after mastering bicycle riding skill, people never forget the way to ride it and operate it easily. This implies that people have embodied expertise to ride a bicycle. It is difficult to transfer embodied expertise to people from another people by means of 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 linguistics only. That means unclear of correspondence between embodied expertise and explicit knowledge like linguistic representation.

On the other hand, onomatopoeias are well known as Japanese word expressions that expresses sounds, appearances, motions, or voice of things. Onomatopoeias, which are echoic, imitative, or mimetic words, are basic part of Japanese language, and are used to supplement the shortage of variety of verbs compared to other languages. For example, there are a lot of verbs to express walking in English, such as "plod", "stroll", "strut", "swagger", meanwhile there is an only one "aruku" in Japanese. 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, sensitive and ambiguous feelings [3]. If "onomatopoeia" is new word on you, you 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 the comic book

Japanese people often use onomatopoeias in daily life talk. Such onomatopoeias can make the people communicate each other easily and intuitively. When playing sports, dancing or musical instruments, the people use onomatopoeias to express the skills of them because the people are used to use onomatopoeias. So the people can share the 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, which express embodied expertise, "embodied expertise onomatopoeias" which can facilitate people to intuitively understand the embodied expertise. But there are some problems to translate embodied expertise into the embodied expertise onomatopoeias. One of the main problems is ambiguity of onomatopoeias. The effect or meaning of an onomatopoeic word relies on the context that the word is used. For example, even if an onomatopoeic word is used in different sports, the word doesn't always express same action of the sports. In other words if restricting the context or the situation that onomatopoeias are used, it has possible to use them effectively. An onomatopoeia is easy and intuitive to understand for the people usually use it, besides it is very similar to a fuzzy number in respect to that it doesn't refer one single value but rather to a connected set of possible values. If you can establish how to use it, it may be a useful tool like a fuzzy number.

Translation into embodied expertise onomatopoeias could be considered as correspondence between skill actions and onomatopoeic words. In our study, the correspondence to be clarified is dealt as a task of pattern recognition. There are a lot of actions and onomatopoeic words that we should investigate. Among people, especially Japanese people, an onomatopoeia is easy and intuitive to understand as well as a

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fuzzy number. It is a strong communication tool among the people. Our study attempted to clarify the correspondence between a sort of skill actions and onomatopoeic words.

It is also expected that the correspondence will be useful to evaluate 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 to design robot motions. So the study can contribute to the development of the research field of HRI, human robot interaction.

Among a lot of skill actions, our study chose and adopted a skill action of Japanese penmanship "Pen Shodo" using a pen to be translated into onomatopoeic words. Japanese calligraphy "Shodo" using a brush is one of the popular arts in Japan. "Pen Shodo" is also one of the arts, meanwhile improvement of the skill of "Pen Shodo" is useful for handwriting in business or daily life. Pen-writing skill is composed of several writing features. The important ones are pen pressure and pen speed that a writer puts on his/her pen when writing. These two features have a big effect on the appearance of characters written with a pen as well as "Shodo" characters written with a brush.

We investigated the correspondence between the writing features and onomatopoeic words. On the basis of the investigation result, we have constructed classes of onomatopoeic words and developed a classification system. The system we have developed can output a class of onomatopoeic words by inputting pen pressure and pen speed. By using the system, it is expected that users can recognize how different their own pen-writing features and the ones of experts are by checking the difference of onomatopoeic words. As the result it is expected that the users can make use of the onomatopoeic words to improve their own pen-writing skills of "Pen Shodo".

II. Related works

There are some works related 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 skill of playing a particular instrument called a cello. They investigated an Abductive Logic Programming (ALP) framework to find appropriate hypotheses to explain both professional and amateur skill performance. Meanwhile, there are some related works to study modeling of sports such like golf and baseball [7]–[11].

There are also some works 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] hired onomatopoeias for recommendation system of online shopping. Hashimoto et al. [14] developed e-learning system for Japanese onomatopoeic expressions. Ueda et al. [15] proposed and provided a system which supported communication between Japanese patients and foreign doctors by applying the onomatopoeia evaluation system to medical use.

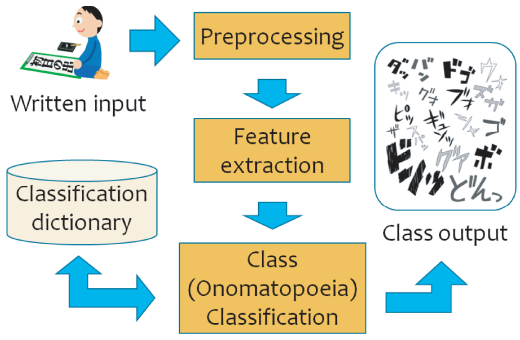

Fig. 2. Proposed model to verbalize writing-skill features

As mentioned the above the studies regarding onomatopoeias dealt with few topics related to human motions, skill actions, and so on. Our study will help to bridge between the studies related to embodied expertise and onomatopoeias.

III. Proposed model

Learners of "Pen Shodo" usually look at the characters written by the experts of "Pen Shodo", and improve their skills to write beautiful characters similar to the one of the experts. In a progress of their improvement, they have to repeat trial and error to detect the difference between their own writing characters and the ones of the experts. It is easy task to detect rough difference of character appearance, but it isn't so easy to detect detailed difference. The experts can instruct the learners how to operate a pen to write a beautiful character, but they aren't always experts to instruct how to do it.

Linewidth of character stroke or pen-ink shade on a sheet of paper are important factors that affect esthetics of characters of "Pen Shodo". Dynamics of pen operation shall determine the linewidth of character stroke or the pen-ink shade. The learners attempt to watch the dynamics of experts' pen-writing operation to learn beautiful character, however it is a tough task for them to precisely recognize the time fluctuation of pen pressure and pen speed. 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 instruct the learners to learn the writing-skill regarding pen pressure and pen speed.

Our study deals with pattern recognition to verbalize the writing-skill features. Fig. 2 illustrates the flow of our system. As illustrated in Fig. 2, the system is composed of preprocessing, feature extraction, and classification as well as general pattern recognition system. The learner of "Pen Shodo" writes a character, and time series data of his/her writing trajectory are inputted to the system. The preprocessing divides the time series data into each stroke which is composed of the character. The feature extraction calculates pen pressure and pen speed for the each stroke.

TABLE I

ONOMATOPOETIC WORDS

Alphabetical notation	Phoneme of Japanese	Japanese Kana (syllabic Japanese script)
su	/su/	す
su’	/suQ/	すっ
zu’	/zuQ/	ずっ
sû’	/suHQ/	すーっ
shu’	/sjuQ/	しゅっ

The classification classifies the pen pressure and the pen speed into classes of embodied expertise onomatopoeias. The system outputs an onomatopoeic-word list according to the order of the strokes.

If both the learner and the expert write same character using the system, the learner can confirm and learn the difference of their onomatopoeic-word lists the system outputs. It is expected that the learners who are familiar to onomatopoeias can recognize the difference intuitively and improve their writing-skill effectively.

IV. PRELIMINARY INVESTIGATION

In order to construct a classifier system as illustrated in Fig. 2, it is need to prepare an appropriate classification dictionary of embodied expertise onomatopoeias. The ambiguity of an onomatopoeic word relies on the context or the locality that the word is used. For example, the sound of a clock may be tick tock in English, or katchin katchin in Japanese. In addition to this, multiple onomatopoeic words sometime express same sound, motion, and so on. Thus it is no wonder that there exit several onomatopoeic words to express same or similar pen pressure or pen speed. In this case it isn’t necessary to classify and distinguish such onomatopoeic words. It is rather appropriate to unify the onomatopoeic words into a class which includes the onomatopoeic words to express same or similar pen pressure or pen speed. It is useful to be able to distinguish among the classes.

To construct a classification dictionary of the classes, we investigated a similarity among onomatopoeic words related to pen-writing. There exit a lot of onomatopoeic words, and this paper chose five simple onomatopoeic words: “su(/su/)”, “su’(/suQ/)”, “zu’(/zuQ/)”, “sû’(/suHQ/)”, and “shu’(/sjuQ/)” as shown in Tab. I. These words are familiar to Japanese people and often used to operate a pen. Each of these words consists of one syllable in Japanese which has one or ones of the sounds: resonant(unvoiced sound), geminate consonant, sonant(dull sound), long sound, and contracted sound. Comparing with the words can be connected to explore and clarify some effect of the five sounds for pen pressure and pen speed.

A. Data Acquisition

The subject imagined an onomatopoeic word shown in Tab. I, and he/she drew a horizontal line. The ten subjects are all in twenties (nine men and one woman) and right-handed. They did the operation 10 times for every onomatopoeic word, and 5 times in the latter half were used for the investigation. They operated a stylus pen and a pen tablet of Wacom Intuos4 Tablet. The line was drawn by starting from left to right. A (x, y)-coordinate and a value of pen pressure were sampled every 60 msec. Fig. 3 shows the actual condition of the experiment.

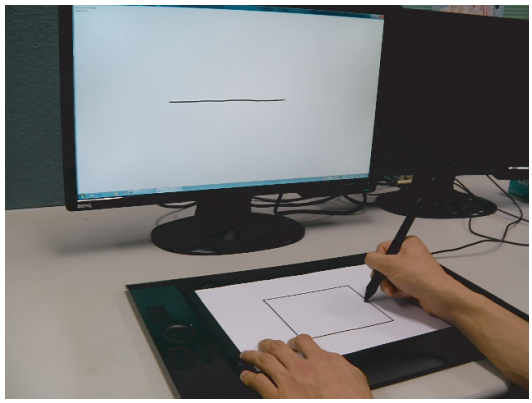

Fig. 3. Actual condition of the experiment

We adopted the horizontal line as a basic element of a Japanese character for the investigation. A Japanese character is composed of a combination of several strokes. The horizontal line is also one of the standard strokes.

B. Clustering based on Statistical Analysis

The scatter diagrams of pen pressure and pen speed are shown in Fig. 4. The each sample point plotted indicates the average value of pen pressure and pen speed of an operation that the subject drew the horizontal line as imaging an onomatopoeic word. The samples are total 50 (10 subjects $\times$ 5 times) per an onomatopoeia. The upper left of Fig. 4 indicates the scatter diagram of both “su’(/suQ/)” and “su(/su/)” to recognize the effect of the presence of geminate consonant (/Q/). The upper right indicates the scatter diagram of both “su’(/suQ/)” and “zu’(/zuQ/)” to recognize the effect of the presence of sonant (/z/). The lower left indicates the scatter diagram of both “su’(/suQ/)” and “sû(/suHQ/)” to recognize the effect of the presence of long sound (/H/). The lower right indicates the scatter diagram of both “su’(/suQ/)” and “shu(/sjuQ/)” to recognize the effect of the presence of contracted sound (/j/).

As you can see the upper right of Fig. 4, the distribution of “su’(/suQ/)” and “zu’(/zuQ/)” didn’t almost overlap. Thus even a simple linear classifier may have possible to classify the classes of “su’(/suQ/)” and “su(/su/)”. Meanwhile, as you can see the other three scatter diagrams, the distributions of two classes overlapped each other.

Then we conducted detailed investigation by using statistical analysis. We hired Tukey 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 shown in Tab.II and III.

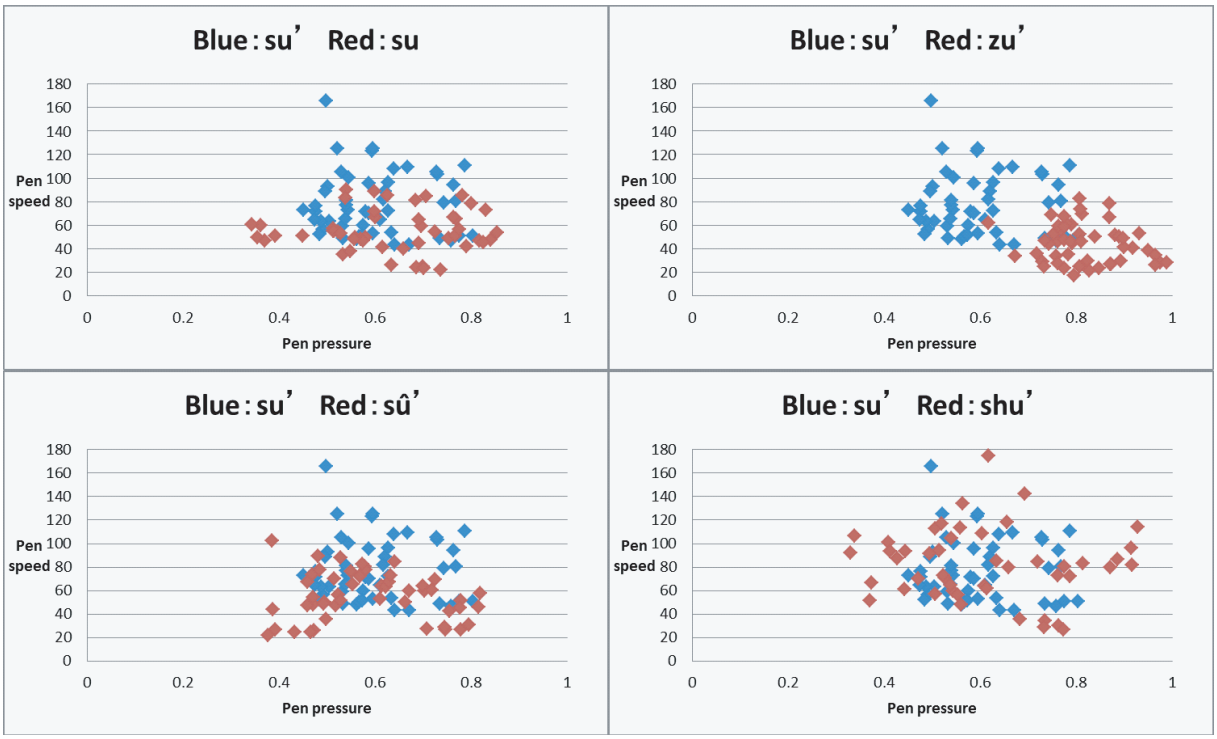

Fig. 4. Comparison between onomatopoeic words using pen pressure and pen speed

TABLE II

RESULTS OF STATISTICAL TEST ON PEN PRESSURE (P VALUES)

	su’ (/suQ/)	su (/su/)	zu’ (/zuQ/)	sû’ (/suHQ/)
su’ (/suQ/)				
su (/su/)	0.6708			
zu’ (/zuQ/)	0.0000**	0.0000**		
sû’ (/suHQ/)	0.9909	0.3809	0.0000**	
shu’ (/sjuQ/)	0.9956	0.8749	0.0000**	0.9190

TABLE III

RESULTS OF STATISTICAL TEST ON PEN SPEED (P VALUES)

	su’ (/suQ/)	su (/su/)	zu’(/zuQ/)	sû’ (/suHQ/)
su’ (/suQ/)				
su (/su/)	0.0003**			
zu’(/zuQ/)	0.0000**	0.2888		
sû’ (/suHQ/)	0.0005**	0.9999	0.2154	
shu’ (/sjuQ/)	0.1513	0.0000**	0.0000**	0.0000**

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

On the other hand, in respect to p-values of the pen speed shown in Tab. III, there are significant differences between “su’(/suQ/)” and the group of three words “su (/su/)”, “zu’(/zuQ/)”, and “sû’(/suHQ/)”. Addition to this, there are also significant differences between “shu’(/sjuQ/)” and the group of three words “su (/su/)”, “zu’(/zuQ/)”, and “sû’(/suHQ/)”.

“su’(/suQ/)” has /Q/, but this fact can’t sufficiently explain that the presence of /Q/ affected the pen speed, because the other words “zu’(/zuQ/)” and “sû’(/suHQ/)” also have /Q/. Allowing for the other words have the combination /z/+/Q/ or /H/+/Q/, the single /Q/ might have affected the pen speed. On the other hand, “shu’(/sjuQ/)” has the combination /Q/+/j/. Hence the combination /Q/+/j/ might have affected the pen speed.

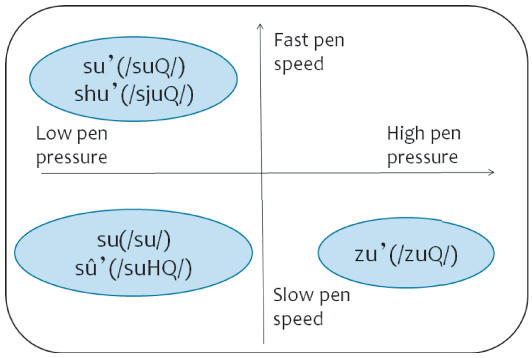

Fig. 5. Clustering based on significant differences

The above consideration is summarized as illustrated in Fig. 5. As illustrated in Fig. 5, three classes of the onomatopoeic words are constructed by considering the significant differences.

C. Clustering based on Classifications between two Onomatopoeic Words

In addition to the statistical analysis, we conducted examinations to classify between two onomatopoeic words. As previously explained, 50 samples (10 subjects $\times$ 5 times) regarding pen pressure and pen speed were acquired for the each onomatopoeic word. The half of them for the each word were randomly selected and used for support vector machine classifier (SVM). The rest of them were for test data. C-SVM with the gaussian kernel($C = 5, \sigma = 0.2$) were hired for the classification between two words by using both pen pressure and pen speed. For the examinations, 100 trials were done and the average classification rates are shown in Tab. IV. For example, the lower-right cell in Tab. IV shows 0.82(82%) between sû'(/suHQ/) and shu' (/sjuQ/).

Tab. IV can be represented as an undirected graph representation illustrated in Fig. 6. The vertex represents an onomatopoeic word. The edge represents classification between two onomatopoeic words. The numerical value on the edge shows the classification rates between two onomatopoeic words.

It is considered that unless the classification rate is high it is difficult to classify between them. Fig. 7 indicates that if the classification rate on the edge is more than 70% then the edges are deleted from the graph representation. As the result, the three cliques are found. The three cliques are same composition to the three classes illustrated in Fig. 5.

V. Classification Experiment and Discussion

We constructed the following three classes A, B and C consist of the onomatopoeic words on basis of the results of the statistical test and the clustering respectively shown in Fig. 5 and Fig. 7.

1) A ={su' (/suQ/), shu' (/sjuQ/)}
2) B ={su (/su/), sû' (/suHQ/)}
3) C ={zu'(/zuQ/)}

The experiment hired SVM to classify the three classes A, B and C by using both pen pressure and pen speed. The parameters of SVM are same to the ones used in the section IV-C. The experiment is multi-class classification, and a one-versus-the-rest classifier and a one-versus-one classifier were used. 50 samples (10 subjects $\times$ 5 times) regarding pen pressure and pen speed were acquired for the each onomatopoeic word. Thus the classes A and B have 100 samples respectively, and C has 50. The half samples for the each class were randomly selected and used for the multi-class SVM classifier. The rest of them were for test data. For the examination, 100 trials were done and the average classification rates are shown in Tab. V.

As shown in Tab. V, the classification rate of the class C is over 90%. Thus it has possibility that the presence of the sonant (/z/) affected as well as argued in the section IV-B The classification rates of other classes are over chance level 33%, but it isn't very high to distinguish.

The words in the classes consists of one syllable in Japanese which has one or ones of the 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 have some relation to the sounds of the words. Especially the presence of the sonant /z/ are likely to have big relationship to strength of pen pressure.

VI. Conclusions

This paper proposed to verbalize embodied expertise. The classifier system was employed to translate pen pressure and pen speed, which are the ones of factors of writing-skill, into onomatopoeic words. Five onomatopoeic words were used to classify pen pressure and pen speed. As the result of the experiment, strength of the pen pressure can mainly correspond to the words which has the sonant (/z/).

On the other hand, there are some remained problems. The first one is that the experiment had used only five onomatopoeic words. There are a lot of onomatopoeic words related to writing-skill. The investigation regarding other words except the five ones should be performed. Secondly, other features of writing-skill need to be adopted for the investigation. This study focused on pen pressure and pen speed, but there are other features of writing-skill, i.e. pen inclination or stroke length. Finally, there exist individual variations regarding correspondence between writing skill and onomatopoeias. The experiment had employed ten subjects and attempted to clarify the generality or the universality of correspondence between writing skill and onomatopoeic words. It is considered that the ambiguity of onomatopoeic words partially depends on the individual variations, i.e. how familiar to onomatopoeias, how skillful with a pen and so on. Considering the individual variations could make the system be a more useful tool for "Pen Shodo" learners. It will also be interesting to investigate the correspondence regarding foreign people except Japanese people, In near future we will address these problems and provide a practical system.

TABLE IV

CLASSIFICATION RESULT BETWEEN TWO ONOMATOPOEIC WORDS

	su' (/suQ/)	su (/su/)	zu'(/zuQ/)	sû' (/suHQ/)
su' (/suQ/)				
su (/su/)	0.71			
zu'(/zuQ/)	0.91	0.76		
sû' (/suHQ/)	0.76	0.67	0.85	
shu' (/sjuQ/)	0.64	0.73	0.90	0.82

TABLE V

CLASSIFICATION RESULT BETWEEN THREE CLASSES

	A ={su' (/suQ/), shu' (/sjuQ/)}	B ={su (/su/), sû' (/suHQ/)}	C ={zu'(/zuQ/)}
one vs the rest	0.64	0.52	0.94
one vs one	0.61	0.45	0.90

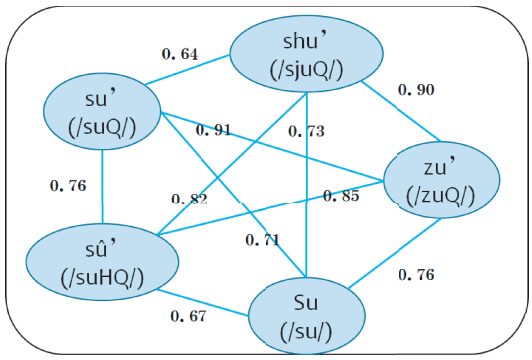

Fig. 6. Graph representation based on classification result between two onomatopoeic words

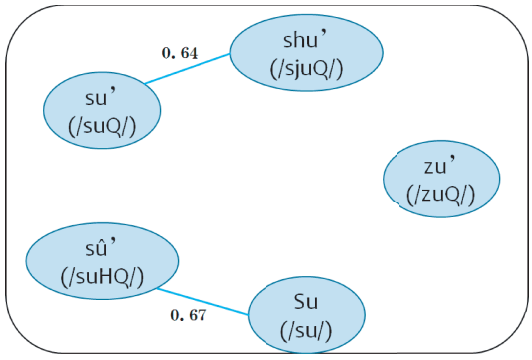

Fig. 7. Cliques in the graph based on the classification result between two onomatopoeic words

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