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Analysis of Prosody in Finger Braille Using Electromyography

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Abstract— **Finger braille is one of the communication methods for the deaf blind. The interpreter types braille codes on the fingers of deaf blind. Finger braille seems to be the most suitable medium for real-time communication by its speed and accuracy of transmitting characters. We hypothesize that the prosody information exists in the time structure and strength of finger braille typing. Prosody is the paralinguistic information that has functions to transmit the sentence structure, prominence, emotions and other form of information in real time communication. In this study, we measured the surface electromyography (sEMG) of finger movement to analyze the typing strength of finger braille. We found that the typing strength increases at the beginning of a phrase and a prominent phrase. The result shows the possibility that the prosody in the typing strength of finger braille can be applied to create an interpreter system for the deafblind.**

I. INTRODUCTION

PEOPLE who have both sight and hearing impairments are known as deafblind. Because of their impairments they face many problems in their normal daily life. It is particularly difficult for totally deaf and blind people to acquire vital and sufficient information necessary for daily living, compared with sighted-hearing people. To obtain information for living, they use tactile sensation instead of auditory and visual sensations. There are several communication methods that involves tactile sensation, such as finger braille, manual alphabets, and the print-on-palm method. Deafblind people are able to communicate with sighted-hearing people through interpreters. However, some problems arise in such conversations, such as the lack of privacy for deafblind people and passive-prone information retrieval. How can deafblind people communicate without interpreters? Assistive technology, such as simultaneous interpreting system, to support deaf-blind people is necessary so that they can communicate without interpreters. We focused on finger braille as the medium to be used in our interpreting system.

In finger braille, the fingers of a deafblind person are regarded as the keys of a brailler (a braille typewriter). A person types braille codes on the fingers of the deafblind person. Compared with other methods, finger braille is fast in transmitting the codes so it is adequate for real-time communication. We believe that prosody included in utterances is the key to real-time communication. In speech, for example, prosody is information including pitch, rhythm, and pause, that seems to function in transmitting information about sentence structure, prominence, emotions and other forms of information [1]. Spoken languages employ all types of prosody, which enhances the real-time comprehension of the utterances [2]. We hypothesize that there is prosody in finger braille as well.

As physical parameters of finger braille, the speed and strength of finger typing can be considered. In our previous study, we analyzed the timing structure of finger braille, and a prosody rule for finger braille was proposed [3]. In this study, we attempt to identify prosody information from the typing strength of finger braille. We analyzed the influence from the sentence structure, prominence and accent of Japanese on typing strength. Electromyography (EMG) was used to measure the strength of finger typing. The measured EMG signal reflects the typing strength of finger braille; thus, the signal reflects what the interpreter means accurately. On the other hand, the pressure on the point where the finger presses down reflects what the deafblind receives. In this study, we attempt to measure typing strength of finger braille from the viewpoint of the interpreter's intension.

We will be able to develop a new prosody rule by combining information on time structure and typing strength if a strength transition due to prosody can be found.

In this paper, we describe the prosody of finger braille and the muscle strength measurements in finger braille typing in Section 2, a measurement experiment using surface electromyography (sEMG) in Section 3, the results in Section 4, the discussion in Section 5, and the conclusions and future work in Section 6.

II. METHOD

A. How to Measure Movement of Finger Braille

In finger braille, the fingers of a deafblind person function as a brailler on which an interpreter types braille codes, as shown in Fig. 1. A braille code consists of a combination of six dots. In finger braille, six dots are assigned to the index, middle, and ring fingers of the interpreter's hands. The interpreter presses down the corresponding fingers of his/her hands simultaneously to express a braille code. The Japanese braille code system consists of 46 codes which express *kana*

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Fig. 1. The left side of the picture shows the hands of a deafblind and the right side shows the hands of an interpreter.

characters (mora with a voiceless consonant) and some special codes. It is possible to express any language that has six-dots braille code system by using finger braille.

The standard position when typing finger braille is either the deafblind person and the interpreter face each other or they sit beside one another. When they face each other, the hands of the interpreter are stationary on a table. When the interpreter sits beside the deafblind person, the hands of the interpreter are laid over on the hands of the deafblind. A skilled interpreter can type finger braille while standing or walking. In such situations, the interpreter's hands are unstable and cover the deafblind's hands. The appropriate typing position on the fingers to recognize finger braille depends on the deafblind.

The movement of finger braille typing of an interpreter starts by the interpreter placing his/her hands on the deafblind's hands and pressing down one to six appropriate fingers simultaneously on the deafblind's fingers.

On the basis of the above movement in finger braille, we assume typing strength to be a physical parameter of such finger movement. Research on the finger load in finger braille movement has been performed by calculating pressure [4]. In this study, we focused on EMG, which directly reflects motor commands from the brain to the muscles, for the measurement of typing strength of finger braille. It seems to reflect what the interpreter means more accurately. We carried out measurements using sEMG, which imposes less burden on the subjects than EMG measurement with needle electrodes. The movements of all six fingers were similar; however, the typing strength of each finger was expected to be different. The difference in the measured values should be considered.

B. *Prosody of Finger Braille*

Interpreters for deafblind people transmit much information at one time because they must explain what is going on around them along with other people's utterances. In a real-time conversation, the interpreter must transmit the information quickly. One of the features of finger braille is its accuracy and speed in transmitting characters. Between a skilled interpreter and a deafblind person, approximately 350 syllables can be transmitted per minute. Why can a deafblind understand the interpreter even when codes are received one by one so quickly? There is a possibility of the existence of prosody information that is used for comprehension and prediction. If such reason for the quick comprehension is elucidated, it can be applied to develop an interpreter system for the deafblind. Another feature of finger braille is its rhythm. Deafblind people say that the rhythm of typing differs according to the interpreter. Research [4] has revealed that the emotions of the interpreter can be transmitted through changes in the strength and duration of typing finger braille. Information on individuality and emotions may be communicated in the prosody of finger braille.

In previous research, we analyzed the time structure of finger braille to clarify the existence of prosody. In our analysis, the duration between the onset of pressure of one typed finger code and the onset of the next one was defined as the duration of the typed code. The durations of typed codes for one sentence were compared. It was observed that the duration of the last code of each phrase was longer than that of other codes. It was also shown that the durations of the last code of a prominent word and the code just before the prominent word were markedly longer than the others. These results indicate that a longer duration of typed codes clarifies the boundary of each phrase or prominent word. From these results, we suggest that prosody could also be reflected in the typing strength of finger braille

In this study, we observed changes in typing strength of finger braille in terms of the following: (1) Influence due to Japanese accent, (2) changes at the boundary of phrases and (3) changes at a prominent word. The accent indicated in (1) is the allocation of relative strength and pitch of a voice that is defined in each word. In the Japanese language, it is indicated in the pitch of a voice. Interpreters of finger braille might be influenced by a Japanese accent, if they are Japanese. In that case, it is expected that the typing strength of finger braille will be influenced by a Japanese accent. The changes indicated in (2) are expected to exist for the segmentation of phrases. In finger braille, braille codes are presented sequentially; however, the boundary between phrases is not clearly indicated in the code. A method for the segmentation of phrases is needed for the deafblind to understand interpreter's utterances. We expected that changes in strength would clarify the boundary between phrase. It is expected that the phenomenon indicated in (3) identifies a certain phrase of utterance from before or after the phrase on which the interpreter intends to focus. In speech, the identification is indicated as an increase in the pitch of a voice. We expected some changes in strength to also emphasize the phrase for the identification. The changes indicated in (2) and (3) are confirmed as extended durations of finger braille typing. In this study, such changes were investigated in terms of strength.

The method of analyzing finger braille in this research is as follows. First, we determine values corresponding to each finger's movement from sEMG signals. Next, the value that represents the strength of each braille code is calculated. Then, the value of each code is compared with the structure of the sentence to examine the features in code and phrase units. Furthermore, the value is also examined for sentences that have a prominent word.

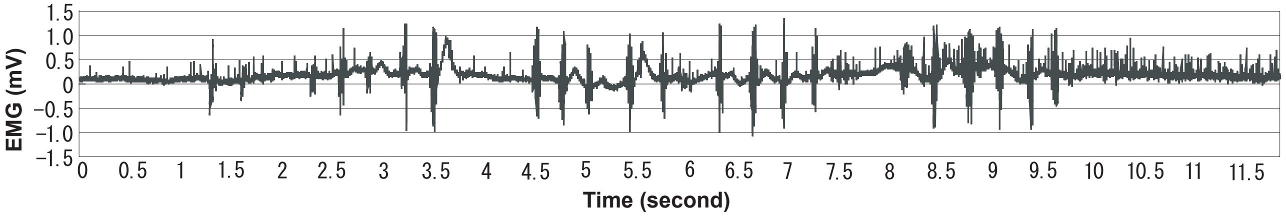

Fig. 2. Recorded sEMG signal of the fingers' movement (left hand).

III. EXPERIMENT

A. Sentences Used

A male finger braille interpreter, who had more than three years of interpreting experience, was the subject of the sEMG measurement. The subject was instructed to type a sentence written on a paper. The sentence was read aloud simultaneously so that the measurement reflected a normal conversation.

In the first measurement, we measured the sEMG signals of the fingers used when the subject typed braille codes without special codes as standard data, because we confirmed in our previous research that duration of finger braille typing is extended in special codes. Five different sentences were used; each sentenced was repeated three times. There were 381 recorded codes in total.

In the next measurement, we measured the sEMG signals of the fingers used when the subject typed sentences that included prominent words. The subject was instructed to give the answer

wa ta shi ha a su a ni to ka ra o ke ni i ki ma su.

(I will go to karaoke with my brother tomorrow.),

to the following questions:

Question 1: i *tsu o ni i sa n to ka ra o ke ni i ki ma su ka?*

(When will you go to karaoke with your brother?)

Question 2: a *su da re to ka ra o ke ni i ki ma su ka?*

(Who is going to karaoke with you tomorrow?)

Question 3: a *su o ni i sa n to do ko ni i ki ma su ka?*

(Where are you going tomorrow with your brother?)

The answers given by the subject to all the questions put forth comprise the same words; however, the positions of the prominent words changed according to the question. The answers to the three questions were recorded, repeating each question three times. There were 159 recorded codes in total.

B. EMG Measurement

The sEMG was carried out using compact active electrodes by the Laplacian EMG method that was previously developed [5]. It was confirmed that sEMG signal could be measured locally. The electrode of the equipment was connected without using a wire; thus, artifact caused by such a wire was not a concern. Amplified EMG signals were sampled at a rate of 2 kHz and low-pass filtered at 5.3 kHz and high-pass filtered at 1 kHz. The subject sat in a comfortable position with his forearm muscle relaxed and typed finger braille on his lap so that the sEMG signal was not mixed with other sEMG signals. In this measurement, the typing strength in the movement of the index, middle and ring fingers of both of the interpreter's hands were measured. In finger braille, the flexion movement of the fingers is often observed. The metacarpophalangeal joint (MPJ) predominantly moves, followed by slight movements of the PIPJ and distal interphalangeal joint (DIPJ). Therefore, we measured the sEMG of superficial flexor muscle of the fingers, which controls the flexion movement of the MPJ of those fingers[6].

Measuring sEMG signal gives rise to the possibility of measuring the strength of other peripheral muscles. To avoid this possibility, beforehand, we detected the spot where the sEMG signal was the maximum following each finger's movement. In the measurement, the sEMG signals of the corresponding spots were measured. Because the wrists were placed stably on the table and the forearms remained stationary, finger movement was not considered to be an artifact of EMG.

IV. RESULTS AND DISCUSSION

A. EMG Signals

Figure 2 shows an example of the recorded sEMG signals. Note that signal peaks are shown between 0.5 and 1.5 mV, corresponding to the finger movement of typing.

B. Representative Value

To calculate the representative value for each braille code, the full-wave rectification of the recorded signals was calculated. Then, the full-wave rectification was integrated between the beginning and end of duration of 10 ms centered at each peak and divided by time. The averaged rectified value (ARV) was defined as the representative value for each code. In finger braille, the combination of fingers used is different for each code. The average and standard deviation of ARVs

TABLE I
FREQUENCY OF USE AND ARVS BY COMBINATION OF FINGERS

Fingers		Frequency of use	Average of ARVs
One finger	Index finger	93(24.4%)	0.561
	Middle finger	21(5.5%)	0.383
	Ring finger	42(11.0%)	0.462
Two fingers	Index and middle fingers	84(22.0%)	0.472
	Middle and ring fingers	45(11.8%)	0.428
	Index and ring fingers	63(16.5%)	0.457
Three fingers	All fingers	33(8.7%)	0.415

*Example of combination: the following eight codes that require the use of the index finger only: *a, u, ka, ku, sa, su, ra, ru*.

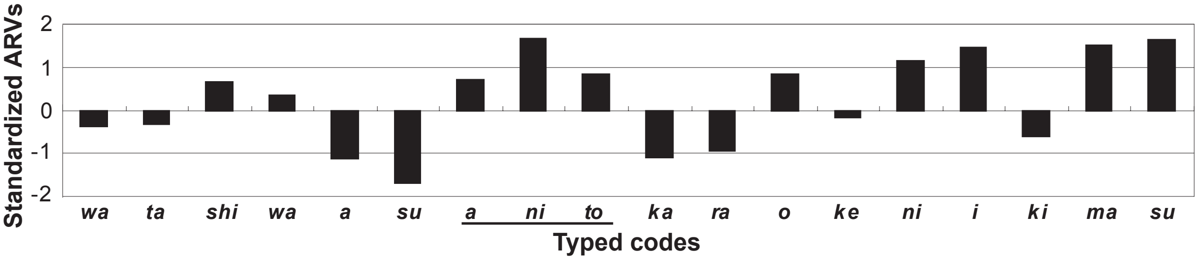

Fig. 3. Example of sentence with prominent word "*a ni to* (with my brother)"

were different for each combination, as indicated in Table I.

ARV was standardized for each combination (seven patterns indicated in Table I). Each value was standardized to a normal distribution in which the average was 0 and the variance was 1. Therefore, positive and negative numbers were included in the value. This standardized ARV was used for the following analysis. To observe the influences of sentence structure and speech on the sEMG signal, the standardized ARVs of codes with accent, at the end of a phrase, at the beginning of a phrase and all the recorded codes are shown in Table II. At the beginning of a phrase, ARV increased. However, no significant differences were seen among these factors.

C. *Prominent Words*

The ARVs of sentences including a prominent word were standardized using the average and variance indicated in section B (above). Fig. 3 shows an example of the standardized ARVs of the same sentence with different prominent words.

The average of the standardized ARVs of all the codes in the prominent words, that of codes just before a prominent word, that of the first code of the prominent word and that of the codes of the rest of the sentence are indicated in Table II. An increase in the standardized ARVs was confirmed for prominent words. In particular, the value increased markedly between a code just before a prominent word and the first code of the prominent word.

TABLE II
AVERAGES OF STANDARDIZED ARVS FOR EACH FACTOR

Factors	Average of standardized ARVs
Code with accent	-0.051
End of phrase	-0.061
Beginning of phrase	-0.108
All codes	-0.015
Code of prominent word	0.127
Code before prominent word	-0.492
First code of prominent word	0.712
Rest of the sentence	-0.091

V. DISCUSSION

A. *Factors influencing sEMG*

The sEMG signals corresponding to each code was observed by measuring the strength of the superficial flexor muscle. The values differed according to the combination of fingers used; thus, standardized ARVs were analyzed. The standardized ARVs were higher at the beginning of a phrase than in the rest of the sentence, but they were only nominally not affected by other expected factors. The reason for this could be that the typing strength of finger braille fluctuated, resulting in unstableness, when compared with its time structure.

B. *Prominent Words*

The standardized ARVs of each code were analyzed. The value increased throughout prominent words. In particular, the value increased considerably between a code just before a prominent word and the first code of the prominent word. It is considered that this increase indicated the beginning of the prominent word. This result indicates the possibility that a prominent word is emphasized by slow and strong typing.

However, prosody has multiple forms of information and many factors are considered to influence these forms of information. In this study, one possible factor of the prosody was indicated. We will collect sufficient data to carry out multivariate analysis in the future.

VI. CONCLUSION

In this study, the measurement of typing strength of finger braille was attempted using sEMG. An increase in the strength of sEMG signal was confirmed at the beginning of a phrase and at the beginning of a prominent word. We are currently investigating other factors that influence the typing strength of finger braille. Also, we are trying to build an environment for measuring the pressure of typing to analyze prosody from the viewpoint of deaf blind perception.

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