Prosody in Finger Braille and Teletext Receiver for Finger Braille

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Abstract
In this paper, we introduce durational rules in text-to-Finger-Braille. Finger Braille is one of the communication methods for the deaf blind and it seems to be the medium most suited to real-time communication and for expressing the feelings of the speaker because of its prosody existing similarly to spoken languages. First, we analyzed duration between two Braille codes in Finger Braille and found that it can be changed according to the structure and meaning of the sentences. Second, we construct durational rules in Finger Braille based on these results. Third, the effectiveness of the rule was examined in listening experiments with a deaf blind person. As a result, it is suggested that durational prosody help listeners to have clear understanding. Finally, we made a prototype of Finger Braille receiver for teletext broadcasting system as a practical application applying this rule.

1. Introduction
People who are both deaf and blind are called "deaf blind". They suffer much inconvenience in their everyday lives due to their handicap. In particular, the deaf blind with serious impairments cannot obtain sufficient information necessary for living, something which hearing and sighted people can do easily.

Typical communication methods for the deaf blind are (1) print-on-palm (tracing letters on the palm of the deaf blind), (2) tactile sign language and finger alphabet, (3) use of a "Bulista" which prints out Braille on tape so the deaf blind can read it and (4) Finger Braille (Yubi Tenji in Japanese) using a Braille code. Of these methods, Finger Braille seems to be the best suited to real-time communication for and for expressing the feelings of the speaker. In Finger Braille, the fingers of the deaf blind are regarded as keys of a Brailler and a translator types the Braille codes on their fingers (Figure 1).

![Figure 1: Typing Finger Braille](image)

About 350 letters can be transmitted between a skilled deaf blind and a Finger Braille translator. As compared to oral transmission of 350-400 letters, Finger Braille is adequate for real-time communication. We believe that a real-time communication method such as speech or Finger Braille should convey not only linguistic information but also paralinguistic and nonlinguistic information. Spoken languages employ all types of prosody, which enhance the real-time understanding of the utterances. Here, we assume that Finger Braille as a real-time communication method also contain such information (we call it the prosody of Finger Braille). By examining the prosodic information of spoken languages, we can determine such factors as the sentence structure, sentence type (e.g., question, declaration, etc.), and prominence. It is suggested that there is similar prosody in Finger Braille.

While equipments for Finger Braille have recently been proposed [1][2][3], no consideration has been given to the prosody. We are going to realize a text-to-Finger-Braille system, which can transmit not only Braille codes but also prosody, such that the deaf blind can understand Finger Braille well.

In this paper, we focus on durational prosody in Finger Braille. First, we analyze the duration between two Braille codes in Finger Braille. Second, we derive durational rules in Finger Braille based on the analysis. Third, subjective experiments are performed to evaluate the rule. Finally, we make a prototype of Finger Braille receiver for teletext broadcasting system as a practical application applying the rule.

2. Japanese Braille code system
Japanese Braille code system consists of 46 codes which express kana characters (voiceless syllable), and some special codes. There are two types of special codes: codes to change consonant and codes to change character set. These codes have to be put before the modified codes. Figure 2 shows the example of a function of a vocalization code, which changes a voiceless syllable to a syllable with voiced consonant.

Codes to change character set have the function to change code set of kana character to the other code set such as number or alphabet. Figure 3 shows the function of the code, which changes kana character to number.

3. Durational analysis of Finger Braille

3.1. Analysis of prominent words
To examine the durational prosody of Finger Braille, we have developed a new input device for Finger Braille (Figure 4). Force-sensitive resistors are adopted to detect finger pressure. The output from the six sensors (three for each hand such as in the case of a Brailler) is input to a PC every 10 milliseconds.
The subject has much experience as a Finger Braille translator. In the recording, the subject was asked to answer questions using the same sentence as shown in the Figure 5. The answers by the translators to all the questions addressed are the same, however, the positions of prominent words change according to the particular question.

Answer: 3 jini chibaekino higashiguchidesu (At the east exit of Chiba station at 3 o'clock)
Question 1: nanjini chibaekino higashiguchidesuka? (At what time will we meet?)
Question 2: 3 jini donoekino higashiguchidesuka? (At which station will we meet?)
Question 3: 3 jini chibaekino dokodesuka? (At which exit will we meet?)

Figure 6 shows the recorded pressure over time. The duration between the onset of pressure of one typed finger code and the onset of the next one is defined as the duration of the typed code.

An example of the duration of all typed codes of the sentence is shown in Figure 7. The sentence was the answer for question 1 of Figure 5. The graph shows that the duration of the last code of each phrase is longer than that of other codes (shown in 91% of all recording). It also shows that the duration of the last code of the prominent word and the code just before the prominent word are appreciably longer than the others (shown in 73% of all recording). These results indicate that the long duration clarifies the boundary of each phrase or prominent word.

3.2. Analysis of ambiguous sentences

In the second recording, the subject was asked to type the ambiguous sentences, (sentences which have two meanings) so as to discriminate their meanings (same code sequences but
different meaning). Figure 8 shows the example of the recorded sentences. The sentence does not give sufficient information to distinguish whether the word ‘wakai (young)’ applies to only the man or both the man and the woman. However, in oral transmission, the meaning can be distinguished from the change of pitch, power and duration or speech rate (prosody of spoken language). We assume that the duration of finger braille has the same function. Seven different sentences that each has two meanings, like the example, were recorded. During the recording, the subject consciously types the sentences as if he tries to convey two different meanings to the deaf blind. For each meaning, the recording was performed twice.

Sentence: Wakaiotokoto onnaga aruiteiru.
(Young man and woman walk.)
Situation A: If only the man is young
Situation B: If both the man and the woman are young

Figure 8: Example of ambiguous sentence

The result of the first recording (about prominent words) suggests that a short duration indicates a strong combination between two codes. Hence we made a “prosodic tree” by combining the codes in order of short duration as shown in Figure 9. The resulting trees (Figure 10 and Figure 11) represent the semantic structure of the recorded sentences and two trees with different meanings are discriminated well. It is suggested that not only the structure of sentences but also the meaning of the sentences affect the duration of Finger Braille. These findings support our assumption.

Step 1: Line up the letters of typed sentences from the left to right
Step 2: Consider the letters at the end of the sentence to be the trunk
Step 3: Consider the duration to be the length of the branch, and connect it to the longer branch on its right side
Step 4: Repeat Step 3 until the process is completed for all letters

Figure 9: Algorithm to generate trees based on duration

Figure 10: The tree under situation A (1: Young man and, 2: woman, 3: walk)

Figure 11: The tree under situation B (1: Young man and, 2: woman, 3: walk)

3.3. Analysis of paragraph

In the third recording, the three translators were asked to type short paragraphs from a news program in order to determine the parameter of the prosody rule. The subjects listen to the news and type the paragraph.

Table 1 shows the average duration of the last code of phrases and sentences, and some special codes. For example, the code, which acts to change an unvoiced consonant into a voiced consonant, has a short duration, while the code that changes the coding system (e.g. changing into the numerical mode) has a long duration. The result indicates that the length of duration has much to do with the function of the special codes. If the deaf blind fail to read the vocalization code, they will misread a following code only. However, if they skip the numberization code, it is possible that more than two codes are not transformed to number and likely misread. It causes a serious influence on understanding of the sentence. Therefore, duration of transform codes became longer, so the codes will not be skipped.

<table>
<thead>
<tr>
<th>Types of the code</th>
<th>Duration (milliseconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Last code of phrase</td>
<td>790</td>
</tr>
<tr>
<td>Last code of sentence</td>
<td>697</td>
</tr>
<tr>
<td>Code for voiced syllable</td>
<td>343</td>
</tr>
<tr>
<td>Code for palatalized syllable</td>
<td>357</td>
</tr>
<tr>
<td>Code to change character set</td>
<td>587</td>
</tr>
<tr>
<td>Others</td>
<td>377</td>
</tr>
</tbody>
</table>

4. Durational rules for Finger Braille

From the above results, we derive durational rules to model the prosody of Finger Braille. The structure of the sentence and the type of the code determine duration of each Braille code. The code is analyzed in advance whether it is the end of a phrase or a sentence, and whether it is a special code. Each code is given the average values as its duration.

5. Output experiments

An experiment has been performed to evaluate the effectiveness of the durational rules. We examined whether the deaf blind have a better understanding when prosody
information is added to Finger Braille output. We have developed a new device for output of Finger Braille (Figure 12). It is available to control duration of Braille codes by PC.

Figure 12: Output device

The subject was a deaf blind who uses the Finger Braille as her major communication means. Before the experiment, there was a rehearsal. The subject could read all the sentences both with and without prosody.

In the experiment, to compare two outputs effectively, the parameter was set as half the recorded time, so the output speed became twice the recorded time. Four essays about animal lives were output. One essay had 450-500 letters and consisted of three paragraphs. Two essays had prosodic information and two had no prosodic information. There were 10 questions concerning each essay, so 20 questions were prepared for each outputs. A finger Braille translator typed the questions, and the subject answered orally. The questions were repeated until the subject understood them completely.

Table 2 shows the results of the experiment. The subject exhibited a better understanding of the output with the prosody rule. The subject felt that the output by prosody were more natural and understandable as to the timing structure of sentences. The similar results were shown in a study of prosody of spoken languages [4]. The result confirms the validness of the prosody rule.

<table>
<thead>
<tr>
<th>Output</th>
<th>Rate of correct answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>With prosody</td>
<td>85 % (17/20)</td>
</tr>
<tr>
<td>Without prosody</td>
<td>50 % (10/20)</td>
</tr>
</tbody>
</table>

### 6. Teletext receiver for Finger Braille

Our output system based on the prosody rule can be a real-time communication method that can help the deaf blind to obtain information. We developed a prototype of Finger Braille receiver for teletext broadcasting system, which will help the deaf blind to use current mass media. Although similar system has recently been proposed [5], there is no consideration about prosody.

In our system, a PC receives the teletext and Braille codes are output according to the durational rules. The outline of the process is (1) receiving teletext, (2) converting kanji text into kana characters, (3) converting kana characters into braille codes, (4) carrying out morphological analysis and syntactic analysis of the teletext sentence, and (5) applying the durational rules.

### 7. Conclusions

In this paper, we introduce durational rules in text-to-Finger-Braille based on the analysis of actual data and the effectiveness of the rule was shown by the subjective experiment. Then we made a prototype of Finger Braille receiver for teletext broadcasting system based on the rules.

In future, we will focus on finger pressure in Finger Braille as another type of prosody. Using the Finger Braille input and output devices, the deaf blind may be able to talk to each other on the telephone. Furthermore, hearing and sighted people may be able to talk to them on the telephone by using a converter for Finger Braille and speech or a keyboard.

### 8. References


