A Study on Bilingual Superimposed Display Method on Digital Signage

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Abstract. In order to solve problems of conventional multilingual display method represented by simultaneous multilingual display and language switching display, the authors have proposed a bilingual superimposed display. The purpose of this study is therefore to propose the method and to evaluate it with an experiment by searching optimal bilingual superimposed display and comparing its reading speed with that of language switching display method. In the experiment, two tasks were conducted as follows; (1) Optimal display search task was carried out to optimize reading speed of bilingual superimposed display based on participants' subjective evaluations using interactive genetic algorithm. (2) Silent reading task was carried out to measure reading speed of sentences with monolingual display and optimized bilingual superimposed display. Then, the model of language switching display was created from the result of reading speed of monolingual display, and the expected reading time of the language switching display was compared with the reading time of bilingual superimposed display. As the comparison result, it was found that the reading speed of the bilingual superimposed display is significantly faster ($p < 0.01$).

Keywords: Digital Signage · Multilingual · Bilingual Superimposed Display · Interactive Genetic Algorithm.

1 Introduction

In recent years, Ministry of Internal Affairs and Communications of Japan is working to expand the functions of digital signage for the 2020 Tokyo Olympic and Paralympic Games, aiming for multilingual support and simultaneous information distribution to prepare disasters[1]. When giving some information to plural people who have different native languages, the current multilingual display method are roughly classified into two types: language switching display (LSD) and simultaneous multilingual display (SMD). LSD is the display method in which contents written in a single language are displayed on one screen for a while, and then it is switched over another language. SMD is the display method in which contents written in in plural languages are displayed simultaneously on one screen. In case of LSD, however, the users may wait for displaying the information in their readable language. In case of SMD, the texts may be too small to read because the information in plural languages are displayed at the same time.

There have been a lot of studies on multilingual display on the digital monitor. Ogi et al. proposed the system that exchanges information between digital signage and the user's smartphone and displays his/her native language automatically[2]. Kim et al. designed a digital signage system that supports multilingual display for foreign tourists which can be used without the Internet access[3]. Matsunuma et al. measured the visibility of graphic text written in Japanese, Korean and Chinese on mobile phones using the parameters of visual distance, reading speed, error rate and subjective evaluation of the readability, then implied that graphic text on mobile phones was adequate for practical use[4]. There also have been a lot of studies on characters given animations. Chujo et al. determined the combination of the reading speed of character strings moving from right to left on the monitor and the number of moving characters displayed simultaneously that participants felt the most readable, then indicated the optimal condition of the display method[5]. Minakuchi et al. determined the emotions that participants felt when they looked at the elemental words of emotions given 9 different motions, then they indicated that words and motion patterns can be each categorized into three groups and effects were varied according to a combination of the words and the motions[6]. As described above, a lot of studies on multilingual display and giving animation to characters have been conducted, however there are no proposal of the new multilingual display method using animations suitable for simultaneous information distribution.

In the this study, therefore the authors have proposed a bilingual superimposed display (BSD) to solve problems of conventional multilingual display methods. BSD is a display method in which information written in different languages with different character modifications are displayed at the same time at the same place. The readability of BSD is supposed to be changed depending on the character modifications such as colors and animations. Therefore, the purpose of this study is to evaluate the utility of BSD by searching optimal modification and comparing reading speed of the optimized BSD and LSD to evaluate their readability. Here, optimal BSD means that the distinctiveness of BSD is the highest, the distinctiveness means how both superimposed languages are easy to be distinguished, and readability means how reading speed is fast.

2 Bilingual Superimposed Display and the optimization Method

2.1 Overview of Bilingual Superimposed Display

As shown in Fig. 1, BSD is the display method in which two sentences written in different languages with effects such as colors and animations are displayed at the same time at same place, thus it aims for the method in which each user whose native language are different can select and read sentences written in their native language when they look at the display at the same time. BSD suppose superimposing any two languages originally. In this study, Japanese and Korean are chosen as superimposed languages, because Korean is the most used language among foreign tourists visiting Japan, and has entirely different script from Japanese[7].

Fig. 1. Concept of bilingal superimposed display.

2.2 Modification Parameters of Bilingual Superimposed Display

The modification for one language can be expressed with 10 parameters which are classified into one of character color, blink, oscillation and weight (character thickness). Thus, one BSD has a total of 20 parameters in order to apply the effects independently to two languages. The character color is expressed by three parameters of RGB color model. The blink is expressed by three parameters of blink cycle, phase difference and minimum opacity, because it is rendered by changing the opacity of characters following sine wave. The oscillation is expressed by three parameters of oscillation cycle, phase difference and amplitude, because it is rendered by moving characters vertically. Weight which means the thickness of the character is expressed by one parameter.

2.3 Optimization Method of Bilingual Superimposed Display Using Interactive Genetic Algorithm

Overview of optimization Method As a method to determine BSD parameters with fast reading speed, optimization based on distinctiveness should be considered. It is however difficult to determine them because there are huge number of combinations of 20 parameters and all of them cannot be evaluated. In this study, an interactive genetic algorithm (IGA) is applied for efficient optimization. IGA is an algorithm that optimizes target individuals by repeating selection, crossover and mutation based on human subjective evaluation. Ordinary IGA performs optimization based on only one person's subjective evaluation. The BSD should be however optimized based on the subjective evaluations of two persons whose native languages are different, since its viewers are both Japanese and Korean speakers. Such a combination of evaluators is called a participant pair from now on.

Details of the Parameters The each range of the RGB value is expressed from 0 to 255. The range of the cycle of blink and oscillation is expressed from 6 to 60 frame which one frame is the time required to update the screen, and it depends on the refresh rate of the LCD monitor. The range of the phase difference of blink and oscillation is expressed from 0 to 360 degree. The range of the minimum opacity is 0–50 %, and the one of the amplitude is expressed from 0 to 10 %. The amplitude is described as the ratio to the height of the imaginary rectangle which covers one character. The range of weight is expressed from 1 to 1000, and this notation, in which big number refers to bold font, depends on web standards[8].

Details of the optimization Method Fig. 2 shows the procedure of the optimization method. First, BSD individuals are randomly generated within the search range and displayed on the screen. At this time, the number of displayed individuals is set to 12 in order to suppress the fatigue of the evaluators. Next, the evaluators evaluate the distinctiveness of BSD based on five grade Likert scale. A participants pair who are two evaluators with different native languages evaluates each BSD individuals as the same time, so that two evaluation results are obtained for each BSD individual. By taking the product of the pair evaluations, the two evaluation values are integrated into one, and the integrated value is used as the fitness of the BSD individual. After the evaluation, 21 parent individuals are selected with a probability proportional to the fitness allowing duplication. Then, individuals of next generation is generated from parent individuals using simplex crossover (SPX)[9]. SPX is the crossover method that requires 21 parent individuals. The above operation is repeated for 14 times. In the 15th generation, evaluators select the 6 individuals with the highest distinctiveness, and they are the final output of this optimization procedure.

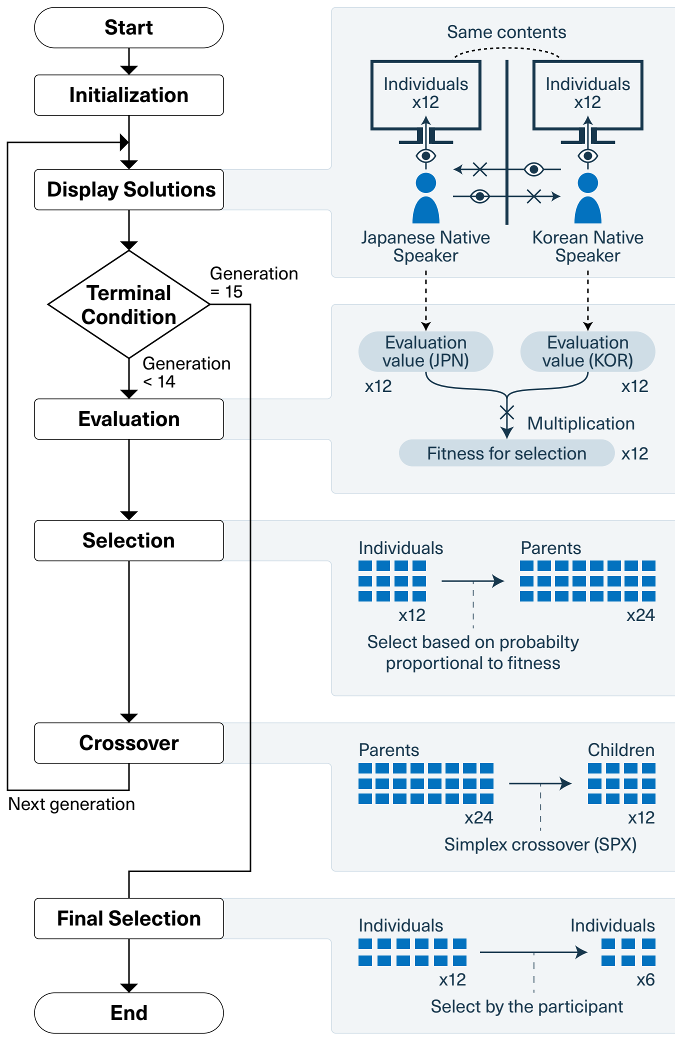

Fig. 2. Flowchart of optimize method and internal process.

3 Experiment of Search and Evaluation of Optimal Display

3.1 Purpose and Overview of the Experiment

The purpose of the experiment is to measure the reading speed on monolingual display (MD) and the optimized BSD to evaluate the proposed BSD.. The flow of this experiment is shown in Fig. 3. In this experiment, the task set consisting of optimal display search task and silent reading task was conducted twice per person. One experiment basically involves four participants, two Japanese native speakers and two Korean native speakers, and one task set was conducted by pairs. Therefore, the results could be obtained for four pairs in one experiment by recombination of pairs in the middle of the experiment.

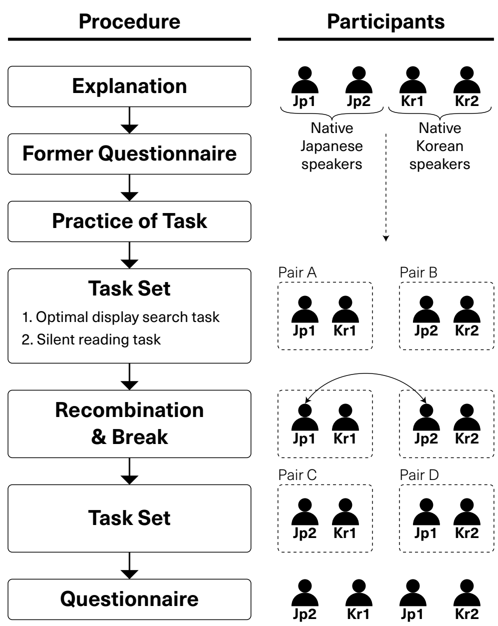

Fig. 3. Experimental Flow.

3.2 Experimental Environment

The experiment was conducted for five days from December 16 to 20, 2019. It was conducted in two timeframes: A (9:00–12:00) and B (13:00–16:00). The schedule of the experiment is shown in Table 1. The participants conducted the task displayed on the monitor using the mouse. Fig.4 shows the layout of the experimental environment. Partitions was set up to prohibit participants from seeing the monitor of others. The screen size of the monitor (LG, 43UD79-B) was 42.5 inches, the resolution was 3840×2160 px, the pixel pitch was 0.2451×0.2451 mm, and the refresh rate was 30 fps.

Table 1. Experimental schedule

Contents	Duration (min)
Overview description	10
Former questionnaire	5
Explanation of experiment schedule	5
Instruction of task	5
Practice of task	15
Task set (first time)	60 (maximum)
Pair recombination/Break	5
Task set (second time)	60 (maximum)
Questionnaire	5
Delivery of reward/Finish	10
Total	180 (maximum)

3.3 Experimental Participants

The participants were 20 Japanese native speakers and 16 Korean native speakers gathered by open call and referrals from acquaintances. All participants have normal corrected vision and no color vision deficiencies. The average age of all 36 participants was 21.8 years (S.D.=4.6).

3.4 Optimal Display Search Task

In this task, the optimal BSD parameters were obtained by the optimization method in section 2.3 based on the evaluation of discrimination. The rendering area of each BSD individual was 1100×300 px, and the background color was always fixed to white. The font was Noto Sans CJK JP/KR with seven weights. The text was drawn in two lines with a font size of 80 px and a line spacing of 70 px. The text was quoted from the corpus and news sites and displayed randomly. The displayed color on the superimposed area of two languages is determined by averaging the RGB value of two alpha-blended colors which is calculated based on two patterns with different combinations of front and back.

3.5 Silent Reading Task

This task was conducted to measure the text reading speed on BSD obtained in the task in section 3.4 and MD. The flow of this task is shown in Fig. 5. When

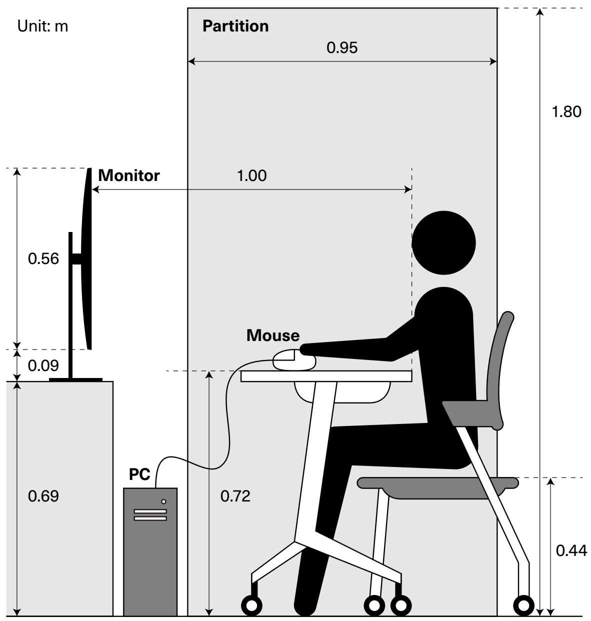

Fig. 4. Position of participants and experimental equipment.

the participant clicked *start* button, a sentence was displayed after a countdown for three seconds. They read the sentence silently, and then they clicked *done* button when they finished reading. They repeated the above operation for 12 sentences.

In this task, the time from displaying the text to clicking the done button was measured. The MD text and the BSD text were displayed alternately. The first four sentences were dummy sets to ignore the learning effect. The rendering area was 3300×600 px for each sentence, and the background color was always fixed to white. The font was the same as the one in section 3.4. The sentences were displayed in random order from a sentence set containing 12 Japanese sentences and 12 Korean sentences. In the case of MD, only the text in the participant's native language was displayed. The text was displayed in four lines with a font size of 80px and a line spacing of 70px. The number of characters in Japanese sentences was set to 40, and the one in Korean sentences was set to the same amount as Japanese. The text was quoted from news sites.

3.6 Model of Language Switching Display

A model of LSD with two languages was created in order to calculate the switching time in which the expected reading time on LSD is the shortest, and then evaluate the reading time on BSD by comparing to the shortest expected reading

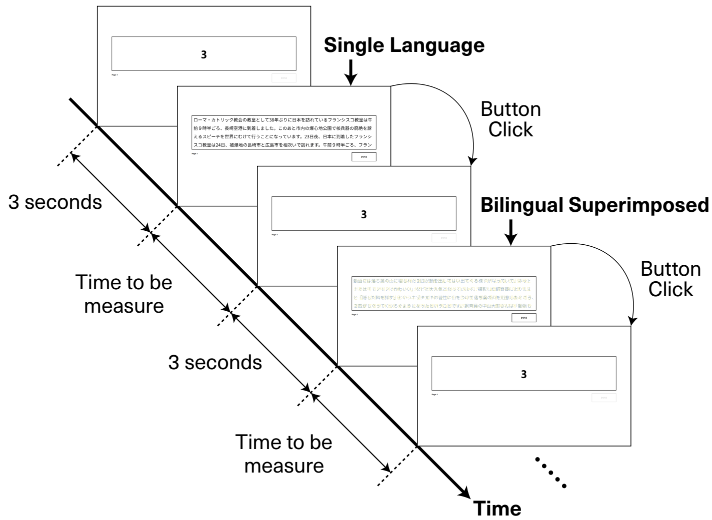

Fig. 5. Overview of silent reading task.

time on LSD with the switching time. Assume that the screen switching time of LSD is fixed to t_s, and the total reading time of sentences written in the viewer's native language is expressed as t_r. If the screen is switched before the viewers have read the entire sentence, they can restart reading immediately from where they left off when the native language sentence is displayed again. Fig. 6 shows an example of the reading time when maximum number of displaying the unreadable page while reading is one, and the maximum number k can be expressed as follows;

$$k = \left\lceil \frac{t_r}{t_s} \right\rceil \tag{1}$$

Therefore, in the case of $(k-1)t_s < t_r \leq kt_s$, the relationship between the reading start time and the required reading time is as shown in Fig. 7, and the expected reading time E can be expressed as follows:

$$E(t_s, t_r) = \frac{3}{2}t_r + \frac{2k-1}{4}t_s \tag{2}$$

3.7 Result

The result of 32 out of 36 participants who successfully completed all tasks were adopted. As the result, 240 data of the reading time on MD and 240 data of the reading time on BSD were obtained. Table 2 shows the results of total reading time for each display method. One-way ANOVA was performed for each display method for the display order of the sentences. As the result, no significant

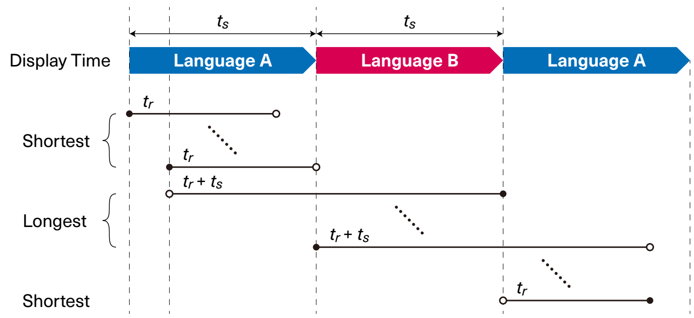

Fig. 6. Example of reading time with bilingual superimposed display.

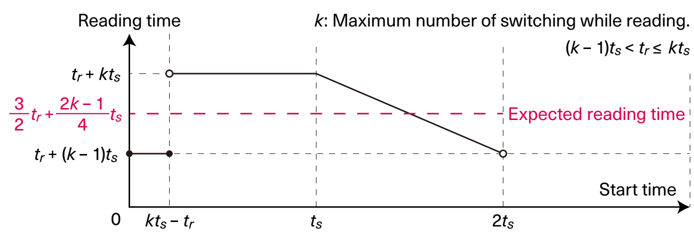

Fig. 7. Model of language switching display.

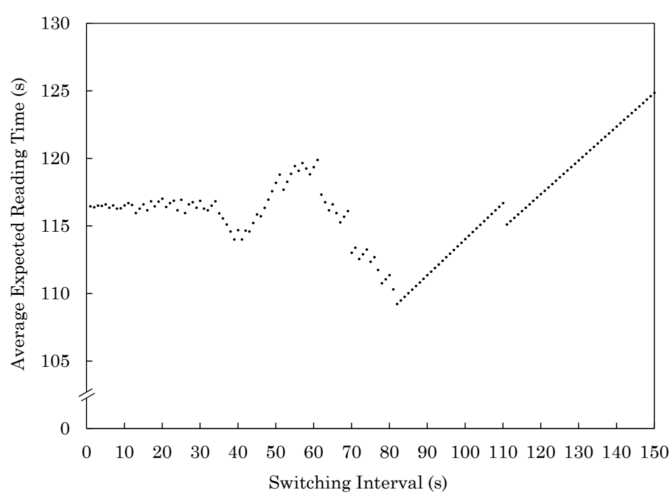

Fig. 8. Average expected reading time with language switching display.

difference was found in the interaction between reading time and displayed order. This means no learning effect was observed in the display order. Fig. 8 shows the results of plotting the average of the expected reading times of all participants on a graph with the switching time t_s varied from 1 to 150 seconds with 1-second steps based on the model of section 3.6. According to Fig. 8, the average of the expected reading time is minimum when $t_s = 82$. This means that the shortest reading time can be expected when all the participants are assumed to be the viewers. Therefore, the expected reading time for each participant at $t_s = 82$ was calculated and shown in Table 2. Table 3 shows the results of comparison between the reading time on BSD and the expected reading time on LSD using the paired t-test. According to Table 3, the reading speeds on BSD were significantly faster than those on LSD.

3.8 Discussions

According to Table 2, the maximum ratio of the reading time on BSD to MD was 3.01 while the average ratio was 1.59. However, all of the partners of participants whose ratio of the reading time was more than double had the ratio lower than the average. It is therefore supposed that optimization failed and some BSD individuals with high readability were generated for only one language.

The LSD model assumed in section 3.6 does not include the time of interruption to search the left-off place when the viewers restart reading. Therefore, under the more realistic model, the expected reading time of LSD is extended and it is supposed that the superiority of BSD on reading speed will be further enhanced.

4 Conclusion

In this study, the authors conducted an experiment to evaluate the utility of BSD by comparing the text reading speed between the optimized BSD and the conventional method, LSD. As the result of the experiment, it was found that BSD with the appropriate parameters had a significantly faster sentence reading speed than the expected reading speed of LSD. However, it was also found that the reading speeds of Japanese native speakers and Korean native speakers differed depending on the combination of BSD parameters. In the future study, It is necessary to investigate the contribution of each parameter to reading speed on BSD.

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Table 2. Result of silent reading task and comparison of bilingual superimposed display and language switching display

Native Language	Monolingual Display (s)	Bilingual Superimosed Display (s)	Expected Reading Time of Switching Display (s)	Ratio (BSD/MD)	Ratio (BSD/E)
Korean	23.99	39.14	56.49	1.44	0.69
Japanese	69.05	126.70	124.08	0.98	1.02
Korean	45.06	82.70	88.08	1.07	0.94
Korean	57.21	86.84	106.32	1.22	0.82
Japanese	42.69	51.80	84.53	1.63	0.61
Japanese	37.93	45.03	77.39	1.72	0.58
Korean	69.72	103.36	125.08	1.21	0.83
Korean	71.66	85.00	127.99	1.51	0.66
Japanese	61.63	137.67	112.94	0.82	1.22
Japanese	81.30	103.78	142.45	1.37	0.73
Korean	77.76	135.02	137.14	1.02	0.98
Japanese	28.10	48.39	62.65	1.29	0.77
Korean	61.65	118.65	112.97	0.95	1.05
Japanese	76.34	84.61	135.00	1.60	0.63
Korean	58.86	66.10	108.79	1.65	0.61
Korean	74.89	95.82	132.84	1.39	0.72
Japanese	69.99	137.56	125.48	0.91	1.10
Japanese	66.08	71.04	119.63	1.68	0.59
Korean	65.04	165.43	118.06	0.71	1.40
Korean	51.19	74.76	97.28	1.30	0.77
Japanese	36.94	62.30	75.91	1.22	0.82
Japanese	35.95	100.57	74.43	0.74	1.35
Korean	61.66	100.02	112.99	1.13	0.89
Korean	110.04	126.90	226.56	1.79	0.56
Japanese	80.38	153.53	141.07	0.92	1.09
Japanese	63.74	59.71	116.10	1.94	0.51
Korean	62.61	115.79	114.42	0.99	1.01
Korean	25.92	78.05	59.38	0.76	1.31
Japanese	28.21	46.51	62.81	1.35	0.74
Japanese	51.65	70.33	97.98	1.39	0.72

Table 3. t-test for reading time of bilingual superimposed display and language switching display

Bilingual Superimposed Display		Expected Reading Time of Switching Display				
M	S.D.	M	S.D.	t	p	d
92.4	36.0	109.2	40.5	−3.089	0.0044**	0.4917

** Significant at the 0.01 level (2-tailed)

d: Effect size (Cohen's d)

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