A Study of Media Representation for Expressing Kansei Information

by

Ken ISHIBASHI

submitted to
Japan Advanced Institute of Science and Technology
in partial fulfillment of the requirements
for the degree of

Doctor of Philosophy

Supervisor: Professor Kazunori Miyata

School of Knowledge Science
Japan Advanced Institute of Science and Technology

March 2014

Acknowledgement

This dissertation represents my "*KANSEI*". Fortunately, I learned a great deal from five years of experience. The experience was enhancing me, and I finished writing this dissertation. Thus, I believe that this dissertation is composed of my feelings and emotions and others. I am grateful to many people who have guided and supported me to create this dissertation.

First of all, I am extremely grateful to my supervisor, Professor Kazunori Miyata in School of Knowledge Science at JAIST. He has great education and research attitudes. He gave me many knowledge and skills, such as writing skill, study approach, and enjoyment of life. I would not have been able to do my research without his help and support. I will pursue my academic career. I would like to sincerely thank him.

In my Ph.D work, I got three internships opportunities. I am very much grateful to Professor Simon Richir at ENSAM (Arts & Metiers ParisTech). I am very much grateful to Professor Anthony Whitehead at Carleton University, especially, he supported my minor research as my advisor. I am very much grateful to Professor Masahiro Takatsuka at the University of Sydney. They gave me good opportunities to develop my research.

I am very much grateful to my dissertation committees, Professor Toshikazu Kato from Chuo University, Professor Yoshiteru Nakamori, Professor Yukari Nagai, and Professor Takashi Hashimoto from JAIST.

In addition, I would like to grateful to my prior supervisor, Professor Ichiro Iimura at Prefectural University of Kumamoto. He supported me to go on JAIST, and taught me the fun of researches.

Furthermore, I would like to thank all people who supported me for five years, especially, the members of Miyata laboratory and my friends.

Finally, I am eternally grateful to my family.

Abstract

"Kansei" means sensitivity, sensibility, and intuition in Japanese. By definition, kansei is complex and vague. In addition, every person has individual kansei; hence, kansei is extremely varied. This diversity makes it difficult to handle kansei information in informatics. This study investigates methods for expressing kansei information using the characteristics of graphic design. In many cases, graphic design can facilitate communication. However, people who do not have sufficient graphic design knowledge and skills cannot fully utilize this attribute.

To solve the problem, a graphic design support method for dealing with each graphic design element is required. In addition, investigation of suitable textual information for expressing kansei information is also required. Recently, Japanese onomatopoeias have attracted attention from various research fields as a helpful information medium. A positive feature of onomatopoeias is the ability to express complex and vague meanings in a short word. Previous studies have reported some practical utilization of onomatopoeias in sport coaching, education, and medical interviews. This study focuses on onomatopoeias because they are useful media to express complex and vague information such as kansei information.

Given the above considerations in relations to kansei, this study set the following two aims: Aim 1) to construct graphic design support methods and Aim 2) to investigate the effectiveness of onomatopoeias. Achievement of these two aims will provide support for utilization of graphic design elements.

Aim 1 is to help people to utilize some graphic design elements easily. This study focuses on three commonly-used graphic design elements, fonts, layouts, and colors, and proposes the following three graphic design support methods.

1. **Font search method**: A font can facilitate communication. Advertising media and product packaging use effective fonts to emphasize their messages. The proposed font search method uses an interactive genetic algorithm and a similarity search. This method allows users to find an appropriate font easily.

2. **Grid layout generation method**: This study targets a grid layout which is a commonly used layout style. The proposed grid layout generation method uses interactive genetic programming. This method enables users to generate their preferred grid layout with only a limited number of operations.
3. **Color scheme search method**: A color scheme is utilized in every graphic design to convey a specific impression. The proposed color scheme search method adopts a statistics-based interactive genetic algorithm that reduces computing cost and maintains the overall impression of a color scheme. This method allows users to obtain their favorite color scheme easily and efficiently.

These methods adopt an interactive evolutionary computation (IEC) framework. IEC makes it possible to suggest some graphic design elements using human evaluations. Hence, IEC-based methods are suitable for achieving the main purpose of this study that is to express kansei information. In addition, IEC can be applied to visual similarity, which is a general recognition of shapes and colors. It is expected that IEC based on visual similarity will be effective for constructing each of three graphic design support methods.

Aim 2 is to investigate the effectiveness of onomatopoeias. This study has the following two analysis targets.

1. **Utilization of onomatopoeias meaning human emotions**: Onomatopoeias can convey complex and vague meanings effectively. This study focuses on the characteristics that make it possible to understand complex information easily and intuitively, and investigates the effectiveness of utilizing onomatopoeias as a kansei medium. The investigation uses a photography system and an image retrieval system with onomatopoeias to conduct some experiments. The results of the experimental investigation may reveal the effectiveness of onomatopoeias and find some appropriate onomatopoeias as kansei media.
2. **Relationship between fonts and onomatopoeia**: Fonts enhance the meanings of onomatopoeias and help people understand meaning visually. To reveal appropriate combinations, this study analyzes the relationship between fonts and onomatopoeias using quantities that represent the font features.

Through these two analyses, this study attempts to clarify the effectiveness of onomatopoeias for expressing kansei information in relation to textual information.

This study makes the following two contributions to kansei study and knowledge science.

1. **Kansei study**: The proposed graphic design support methods consider human evaluations. In an attempt to incorporate human evaluations in each method, each method defined visual similarity for each graphic design element. The defined visual similarities take human perceptions into account. Several experimental results showed good performance by using the proposed graphic design support methods. Therefore, it is expected that the combination of physiological and psychological approaches will improve kansei research; in particular kansei search studies.
2. **Knowledge science**: The proposed graphic design support methods will provide a learning opportunity for fonts and color. Learning is significant for knowledge creation; therefore, the proposed methods will contribute to knowledge creation for graphic design. In addition, the outcome of this study enables to facilitate kansei communication by the effect of graphic design. The expression of kansei information is also significant study approach for human communications; hence, it is expected that the outcome of this study will contribute knowledge science.

Kansei study and knowledge science are strongly related to people. Therefore, it is expected that this study will contribute to research related to human behavior and activities.

Visual information abounds in various media, and if people can communicate their kansei easily via all media, people will be able to understand each other more intuitively and deeply.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

"Kansei" means sensitivity, sensibility, and intuition in Japanese. When people engage with the external world, the experience can be associated with responses to aesthetics and a range of emotions. Such complex and vague feelings are also involved in kansei. Kansei also involves external conditions; people live in different countries with different cultures. In addition, every person has different kinds of relationships with other people. Assuming that kansei is created by a combination of internal and external factors, every person has different kansei; hence, kansei is extremely variable. This diversity makes it difficult to handle kansei information in informatics. Kansei researchers are tackling this important issue. For example, Tsuji [1] has provided types of representative kansei information, shown in Table 1.1.

Previous studies have targeted different types of information to handle ambiguous and complex information. In research related to acoustics, Ishizuka et al. [2] have proposed a method for transformation of theme music based on impressions of stories. This method automatically changes background music depending on an illustration of a story. Hirae and Nishi [3] have constructed an automatic estimation system for individual impressions of classical music. In addition, Yang and Chen [4] have proposed a method for music emotion recognition. This method enables users to retrieve music based on their perceived emotions. These three studies handle acoustic information based on human impressions and emotions. Music has a variety of impressions on people and evokes various emotions. Hence, the outcomes of such studies may contribute to expressing kansei information via acoustic information. In research targeting nonverbal information, Anderson and McOwan [5] and Tariq et al. [6] have

Table 1.1 An example of representative kansei information

(1)	Image information: Graphic, Animation, Painting
(2)	Acoustic information: Music, Voice, Environmental sound
(3)	Textual information: Letter, Text, Poem
(4)	Nonverbal information: Expression, Gesture, Dance
(5)	Modeling information: Design
(6)	Olfactory, Tactile, Taste: Fragrance, Touch

implemented an automated system for the recognition of human facial expressions. These systems can detect emotion in real time via a video. In the near future, people will be able to express emotions in a digital communication, such as video chat, more easily. Kagawa et al. [7] have proposed a video sharing system using a pictogram comment function. This system allows users to post an emotional comment easily, in order to share their emotions and feelings. This system conveys nonverbal information via image information. Recent research has attempted to deal with olfactory or taste information. Bannai et al. [8] have proposed a communication model for background scents using sense-descriptive adjectives for association. This model enhances the impression of image content. Ranasinghe et al. [9] have implemented a tongue-mounted interface for digitally actuating the sense of taste. This interface uses electrical stimulation to provide a taste.

Each type of information is important to deal with kansei information comprehensively; however, specific equipment and environments may be required for each different type of information. Currently, the most commonly used information are image information and textual information. For example, brochures, posters, and magazines use image information and textual information. In addition, previous studies have focused on visual communication based on representative kansei information. Nakatsu et al. [10] have introduced a futuristic communication method by focusing on body expression to express kansei. The study proposed a multimedia system that changes video and sound clips depending on user emotion extracted from their motion. This system allows users to express their emotions as visual information. Wang et al. [11] have presented a chat system using animated text associated with emotional information. The experimental results indicated that the chat system facilitated conversation by communicating emotions using emotional feedback. Si and Igarashi [12] have conducted a comparative analysis between of contexts in relation to visual stimulation using icons. The results of the analysis indicated a relationship between each basic emotion and human motions. Si and Igarashi and Kagawa et al. [7] expect that some icons may be effective communication tools. Sun et al. [13] have implemented a Kinect-based visual communication system. This system uses a Microsoft® Kinect for recognition of sign languages, expressions, and speech. The recognized information automatically generates image information and textual information for tele-communication. In fact, television production also utilizes a great deal of visual information [14]. The visual information can be utilized in various scenes because it can be used as digital and analog content. It is assumed that the combination of image information and textual information is important to deal with kansei information.

This study attempts to express kansei information from the perspective of visual information. In particular, this study focuses on the effect of graphic design. Essentially, graphic design is art, and it can facilitate all types of communication. For example, pictograms are universal symbolic images that people can understand easily. Graphic design is also utilized in posters, presentation slides, websites, advertising media, and other analog and digital content. The biggest benefit of good graphic design is to convey information effectively and efficiently; graphic design facilitates communication. However, people who do not have enough knowledge of graphic design or the skills required to create effective graphic designs are unable to benefit from its use. If this hindrance is removed, it is expected that people will be able to express their kansei information easily and effectively. **This study aims to support graphic design to enable people to benefit from its use.** Graphic design often incorporates textual information. However, textual descriptions are often difficult due to space restrictions. As mentioned previously, kansei information is often complex and ambiguous. Therefore, short texts that can describe complex and ambiguous information are suitable for expressing kansei information. This study focuses on onomatopoeias because there are a great many onomatopoeic words and onomatopoeias can convey information with a short text. In particular, Japanese onomatopoeias enable the expression of complex and vague meanings. Japanese onomatopoeias are used in a lot of package designs [15]. **This study also aims to investigate the effective-**

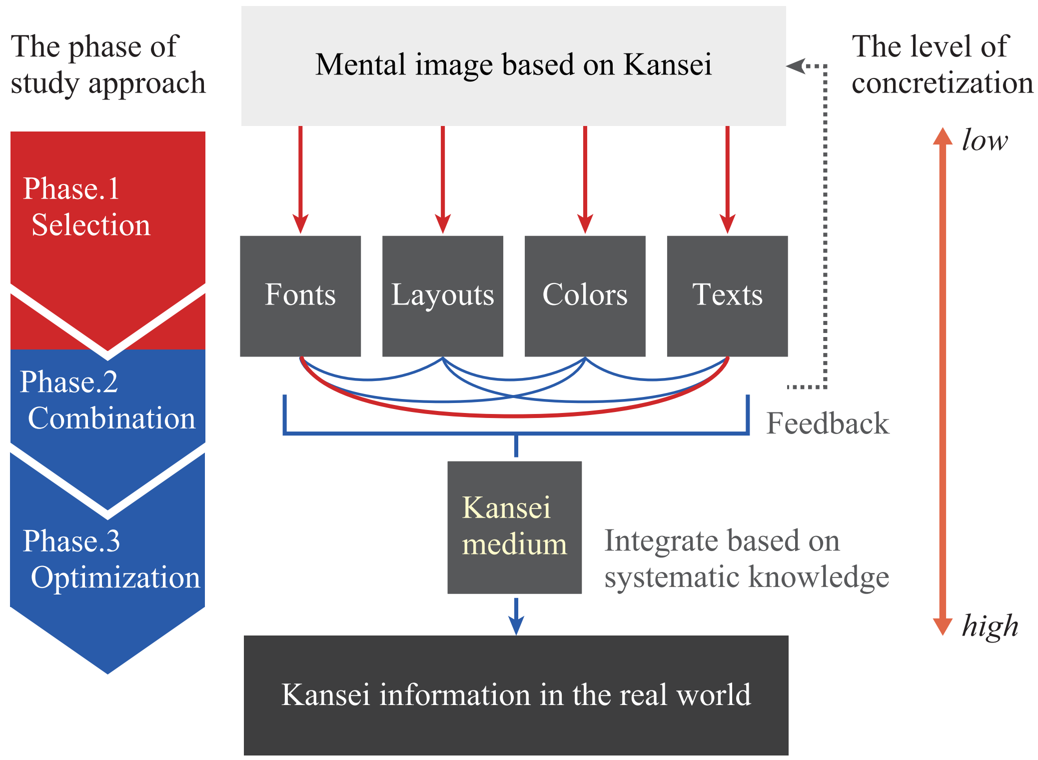


Fig. 1.1 Overview of the study approach

ness of onomatopoeias for expressing kansei information. Therefore, this study explores two approaches: "graphic design support methods" and "investigation of the effectiveness of media expression in textual information." The former involves constructing a support method for various graphic design elements, such as color, layout, and fonts. The latter approach investigates the effectiveness of media expression through onomatopoeias. These approaches will make it possible to express individual kansei information. Here, it is assumed that human emotions are inseparable from kansei information. In this dissertation, kansei information includes human emotions.

1.1 Overview

Figure 1.1 presents an overview of the study. From the perspective of graphic design, a kansei medium that expresses kansei information consists of several graphic design elements. However, it is assumed that the mental image of the final content may be fuzzy. First, this study tries to represent each graphic design element by user selection. This phase determines each graphic design element based on an idea. The second phase considers all combinations of graphic design elements. The combinations affect user selection because impressions may be changed as the combinations of graphic design elements are changed. The last phase optimizes a final kansei medium by integrating all elements based on systematic knowledge of graphic design. Through these three steps, the study approach pursues the main purpose that is to express kansei information visually. In this dissertation, the first phase and a part of the second phase are examined, indicated by a red line and four red arrows in Figure 1.1. Note that blue lines and a blue arrow indicate future challenges. To undertake the first phase, a graphic design support method for choosing each graphic design elements is required. Investigation of suitable textual information for expressing kansei information is also required. Textual information is strongly related to fonts; consequently, this study considers the relationship between fonts and texts.

This study proposes three graphic design support methods and analyzes aspects of onomatopoeias. The three graphic design support methods target three different graphic design elements: fonts, layouts and colors. These methods employ the same framework interactive evolutionary computation (IEC). IEC is an extremely valuable framework because it utilizes human evaluations. This study presents IEC-based graphic design support methods that are customized for each graphic design element. In addition, the study analyzes two aspects of onomatopoeias. One analysis investigates the effectiveness of onomatopoeias for expressing kansei information. In particular, this study considers human emotions, which are one of the essential factors in various communications. The other analysis focuses on the relationship between fonts and onomatopoeia with regard to appropriateness. **The purpose of current phase is to support an utilization of graphic design elements.**

1.2 Graphic design support methods using interactive evolutionary computation

This study proposes a graphic design support model using visual-similarity-based IEC. An overview of the proposed model is shown in Figure 1.2.

This model adopts IEC and a similarity search (SS) or an interactive user

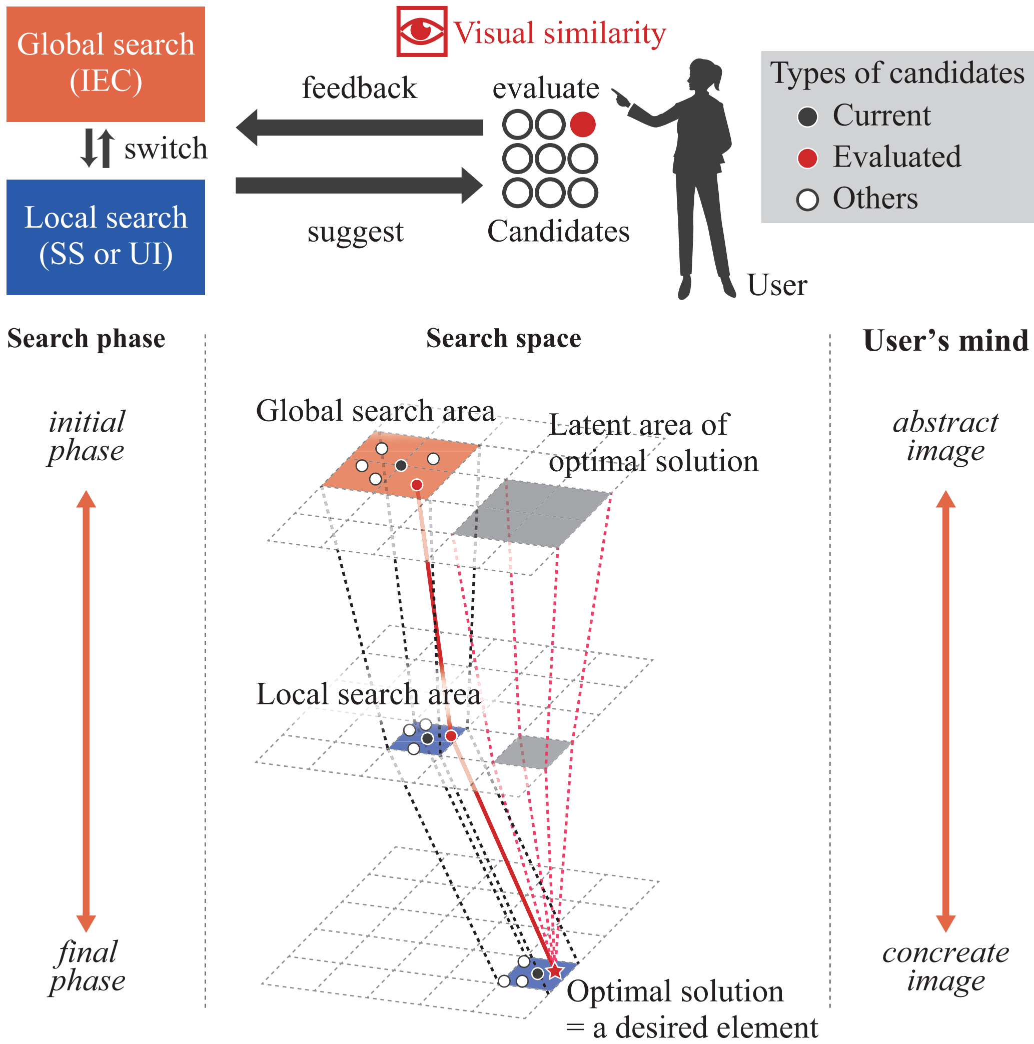


Fig. 1.2 Overview of the proposed graphic design support model

interface (UI). IEC is an evolutionary algorithm that uses human evaluations, and it has a role as a global search tool in this model. IEC creates graphic design elements and presents them to a user. Next, a user evaluates the suggested candidates by choosing the favored candidate. Note that this model does not specify the number of candidates chosen for user evaluation; however, this study uses only a single choice. After the user evaluation process, IEC recreates new candidates based on user feedback. IEC can incorporate user kansei by repeating this process. In addition, the crux of this model is visual similarity, i. e. a general sense to perceive similarity based on shape or color. Most people acquire the ability to discern visual similarity without special training.

Consequently, people can evaluate the candidates they select as best based on a mental image. SS or UI has a role as a local search tool in this model. When a user wants to narrow down the candidates, a local search is required. This model has two search methods that enable users to search their desired graphic design element efficiently. If the user does not have a concrete idea of a graphic design element, the idea of the final version will be concretized gradually as the search progresses. In this model, a user's desired element is contained in a latent area in the search space as an optimal solution. By transitioning from an initial search phase to a final search phase, the search area comes close to the optimal solution. Furthermore, the latent area is also narrowed by the concretization of the desired element. This feature will help novice users search for their desired graphic design elements without special skills or specific knowledge of graphic design.

This study tackles the following three research challenges for supporting graphic design utilizing the proposed model.

1. **Font search method**: Advertising media and product packaging use various fonts to enhance their messages and convey information effectively and intuitively. Font selection is a very important task. Several tens of thousands of fonts are available on the Internet. However, choosing among a large number of fonts is a tedious task, especially as the number of fonts increases. The main purpose of this study is to express user kansei information. Therefore, a goal of this research is to enable users to find a suitable font without any expert skills or knowledge. The font search method is described in greater detail in Chapter 3.
2. **Grid layout generation method**: Graphic design layout can reflect various styles. Each layout style, with varied location and orientation of graphic design elements, gives people a different impression. In particular, this study focuses on a grid layout. A grid layout is a commonly-used style that assigns design elements in a grid-like fashion. A grid layout is a simple style; however, the work becomes tedious as the number of the graphic design elements increases. This study introduces two solutions: reduction of tedious work and generation of desired user grid layout. An IEC-based grid layout generation method is described in Chapter 4.
3. **Color scheme search method**: Color is an important element in all media. Colors give people different impressions depending on the specific

color scheme. Specific feelings are commonly associated with different colors; for example, reddish colors are associated with warmth and bluish colors with cold. Chijiiwa [16] has reported that emotional meaning is universally associated with specific colors; for example, red means danger, yellow is associated happiness, and green is associated with safety. Colors give people specific impressions. However, making an appropriate color scheme is difficult for novices due to lack of sufficient skills and knowledge. Fortunately, many color experts, such as designers and artists, have created and shared over three million color schemes on the Internet [*1]. This collection of schemes is useful; however, it is difficult to obtain a desired color scheme from such a large database. The aim of this study is to find desired user color schemes easily and effectively by utilizing the huge number of color schemes available on the Internet. The details of an IEC-based color scheme search method are presented in Chapter 5.

These three challenges have two common requirements. One is to reflect user kansei into each graphic design element. The other is not to require any specialized graphic design skills or knowledge. Regarding the former, user evaluations are necessary as a feedback system to reflect user kansei information with regard to preferences and aesthetics. Regarding the latter, this study considers ease of use for novice users. The proposed graphic design support model fulfills these requirements.

To achieve the main purpose, each graphic design support method must be practical. Hence, this study sets the following rules for each experimental evaluation.

1. Implement and use a practical application for an experimental evaluation.
2. Set an ambiguous target to evaluate the performance of each method.
3. Set satisfaction or preference as a subjective evaluation item.
4. Set an operation time or a number of operation steps as an objective evaluation item.

Graphic design is utilized in various types of media. To check the effectiveness of each graphic design support method, each proposed method must be implemented in a practical application. With regard to the first rule, popular

[*1] COLOURlovers, http://www.colourlovers.com/ (accessed in October 2013)

content is preferable as an application target. The proposed model also assumes a novice user; consequently, the desired graphic design element is often unclear in their mind. Given this assumption, the second rule requires one to set an ambiguous target when a research participant uses an application in the experimental evaluations. In all kansei research, evaluation of proposed methods must include human evaluation [1]. In this study, the most important evaluation item is user satisfaction or user preference regarding the final content. Therefore, all experimental evaluations include a subjective evaluation item; this is covered in the third rule. Furthermore, operation time or number of operation steps is significant from the perspective of practical use. The fourth rule sets operation time or steps as an objective evaluation item. The four rules determine the experimental conditions and evaluation items for this study.

Many previous kansei studies have evaluated impressions using a semantic differential method. It is assumed that the semantic differential method would be effective for the evaluation of the experiments reported in this study. However, the impression of final content is related to combinations of different graphic design elements. Therefore, this study does not consider a precise evaluation of the impression because each support method targets a single graphic design element. In all experimental evaluations, this study focuses on whether a user can obtain their desired graphic design element.

1.3 Investigation of the effectiveness of onomatopoeias

This study includes the following two analysis targets to investigate the effectiveness of onomatopoeias. Detailed analysis is provided in Chapter 6.

1. **Utilization of onomatopoeias representing human emotions**: The target for this analysis is onomatopoeias that convey emotions. Onomatopoeias are able to convey complex and vague meanings effectively with a short word. This study focuses on the characteristics of onomatopoeias and investigates the effect of utilizing onomatopoeias as kansei media. The investigation uses a photography system and an image retrieval system to conduct experiments. The results of the experimental investigations may reveal the effectiveness of onomatopoeias and may find that onomatopoeias are appropriate as kansei media.

2. **Relations between fonts and onomatopoeias**: The target of this analysis is the relationship between onomatopoeias and fonts, especially appropriate combinations of onomatopoeias and fonts. Fonts enhance the meanings of onomatopoeias and help people understand meaning visually. Japanese animations, comics, and package designs utilize appropriate combinations of onomatopoeias and fonts. However, there is insufficient discussion regarding the relationship between fonts and onomatopoeias. Thus, this kind of knowledge typically requires a designer. To reveal important factors regarding appropriate combinations, further investigation is required. Such an investigation will contribute to achieving the main purpose of this study by clarifying appropriate combinations of fonts and onomatopoeias. For the analysis, this study adopted font feature quantitie (FFQ), which are discussed in Subsection 3.2.1. The FFQs represent the visual features of fonts; thus, this analysis identifies important font characteristics. Furthermore, this analysis approach uses the font search application described in Subsection 3.3.1. This application reduces the participants' tasks, when they select suitable fonts for onomatopoeias.

Through these two investigations, this study attempts to clarify the effectiveness of onomatopoeias for expressing kansei information.

1.4 Dissertation roadmap

Chapter 2 describes work related to graphic design support methods and onomatopoeias. Chapters 3, 4, and 5 present the proposed graphic design support methods for fonts, grid layout, and color, respectively. Chapter 6 shows two investigation approaches regarding onomatopoeias and discusses results. Chapter 7 summarizes all research topics and discusses the contributions of this work for kansei research and knowledge science. Chapter 7 also presents suggestions for future work.

Chapter 2

Related work

This dissertation focuses on the graphic design and the expression of digital media for the purpose of facilitating communication. This chapter introduces two types of relevant fields of study: the study of graphic design support methods and the study of onomatopoeias. Sections 2.1, 2.2, and 2.3 present graphic design support methods for fonts, layout and color, respectively. Section 2.4 describes the study of onomatopoeias.

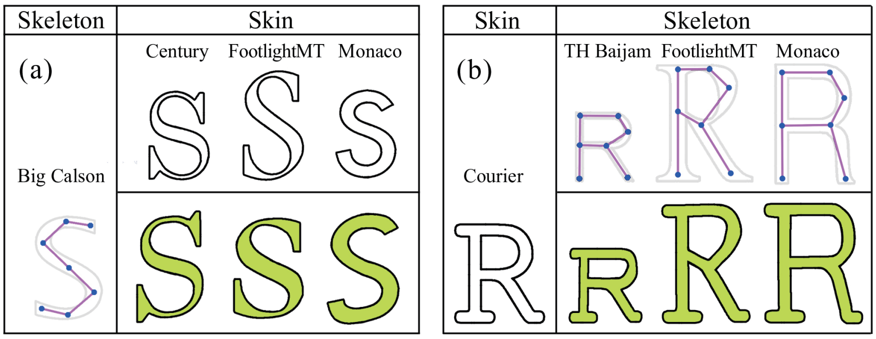
2.1 Font support methods

Font generation and font selection are the main approaches in font support.

2.1.1 Font generation methods

Zalik [17] has proposed a font editing system that allows users to edit each font shape easily. As automatic methods for generating special fonts, Shin and Suzuki [18] have proposed a system for handwritten-style font generation, and Goda et al. [19] have presented a texture transfer method to generate artistic shodo fonts. Lau et al. [20], Suveeranont and Igarashi [21], and Yoshida et al. [22] have implemented similar automatic font generation systems based on a parametric technique. Figure 2.1 shows the results of each system. As other approaches, Wada et al. [23], Hotta et al. [24], and Nozawa et al. [25] have proposed font generation methods involving a fuzzy reasoning method that uses human impressions. These methods generate various Japanese fonts using user selection of impression words, as shown in Figure 2.2. In addition, Unemi and Soda [26] have proposed an IEC-based support system for font design. Their

(a) Lau et al., 2009



(b) Suveeranont and Igarashi, 2009

(c) Yoshida et al., 2010

Fig. 2.1 Results of each system

Fig. 2.2 Examples of the method proposed in [24]

method allows a user to generate various fonts by deforming each stroke of a font based on user evaluation.

These approaches transform several letter parts and combine them; however, it is difficult to generate unique fonts, such as a designer font. Some software developers have also made font generation systems available on a website[*1]. Nowadays, many new fonts are designed by font designers, and a countless number of free fonts are available on the Internet. Although there are a significant number of fonts, it is difficult to select an appropriate font from various candidates. This study addresses these problems and presents an easy and effective way to make a selection. In addition, the proposed method is able to handle some unique fonts.

2.1.2 Font search methods

Tode et al. [27] have proposed a method of selecting fonts by specifying several impression words. However, it is difficult to add a new font because this method first requires ample data about human impressions. In contrast, the proposed method makes it possible to add many new fonts automatically. Thus, the manual development of a font database is not required.

In other previous studies, Solli and Lenz [28], Cutter et al. [29], and Kataria et al. [30] have proposed image retrieval methods. These methods use font feature data, as shown in Figure 2.3. This approach does not require developing a database manually. The proposed method adopts this approach.

[*1] Fontstruct™: http://fontstruct.com/ (accessed in October 2013)

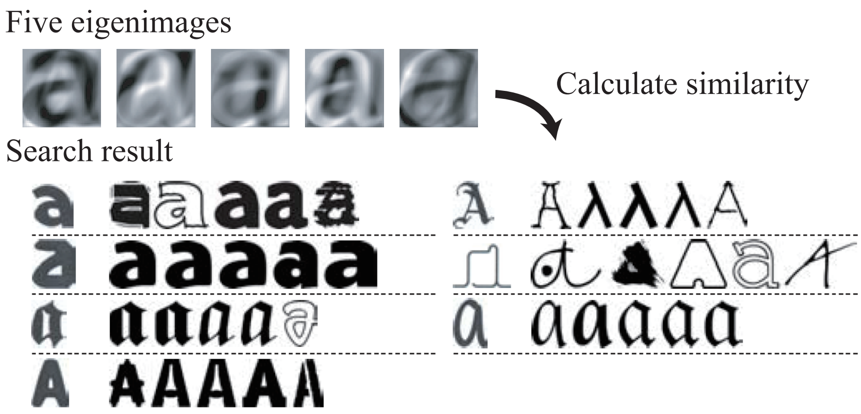


Fig. 2.3 Font retrieval results from [28]. The upper figure shows eigenvectors, which represent the font feature data (modified figures from [28])

2.2 Grid layout support methods

Existing studies have targeted grid layouts to create digital media, such as photo collages, comics and websites. This section introduces existing methods regarding photo collages and some applications using grid layouts.

2.2.1 Photo collage generating methods

Atkins [31] has proposed a blocked recursive image composition (BRIC) as a grid layout generating algorithm. Xiao et al. [32] used the BRIC to develop a mixed-initiative photo collage authoring system. BRIC generates a grid layout using a tree data structure. When users choose some photographs, this system automatically composes a grid layout based on the photographs' information (sizes and aspect ratios). BRIC allows users to generate a collage easily and effectively. Figure 2.4 illustrates the BRIC photo layout creation process and its data structure. However, due to the automatic generation, the structure of this grid layout is not editable.

Rother et al. [33], Wang et al. [34], and Goferman et al. [35] have proposed automatic photo collage generating methods. These methods create different types of photo collages on the basis of grid layouts, as shown in Figure 2.5. However, these methods have a weakness. Owing to some technical limitations, they cannot generate a desired grid layout completely.

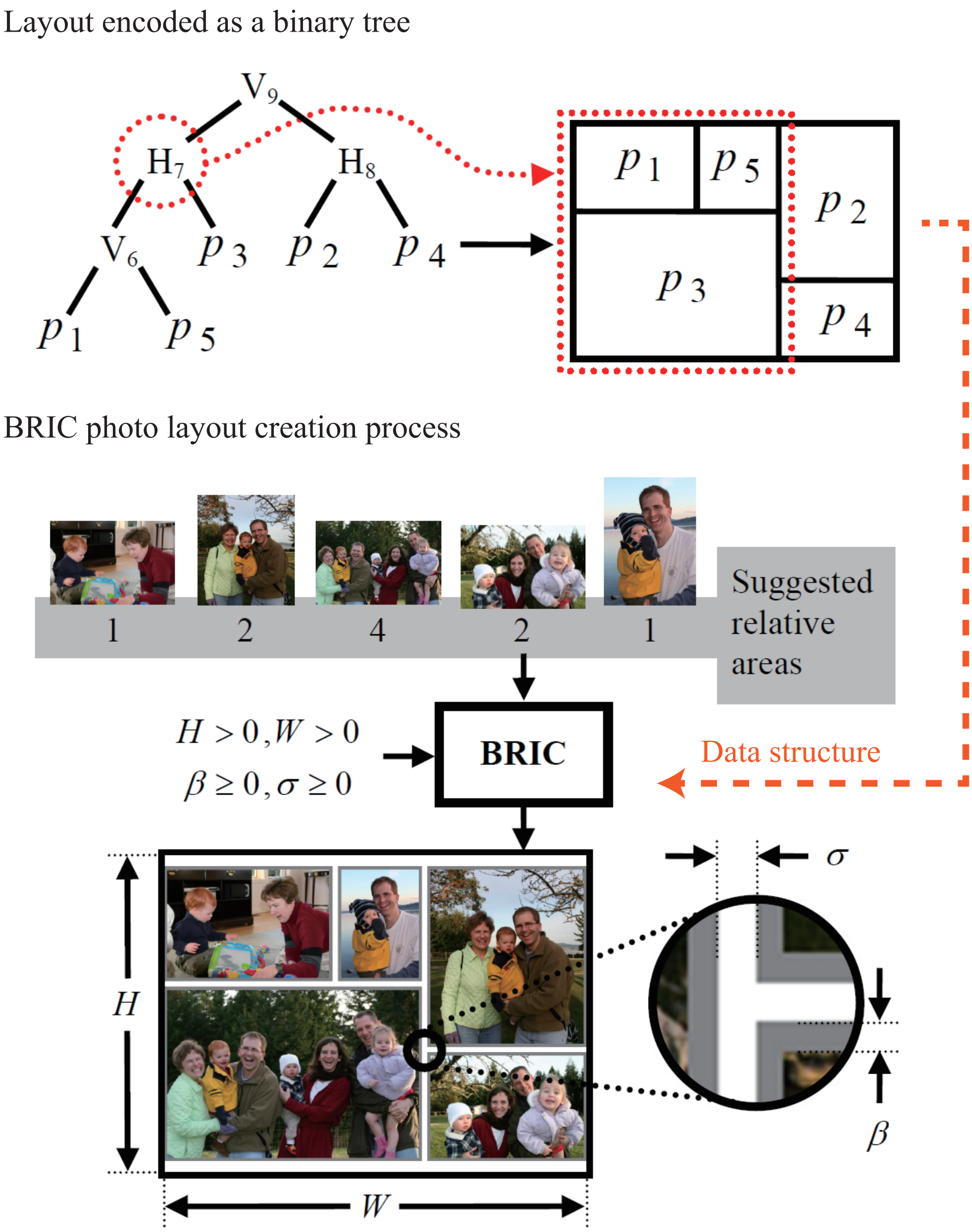


Fig. 2.4 Overview of BRIC-based photo collage generation and its data structure (modified figures from [31])

Fig. 2.5 Three examples of photo collages using conventional methods: upper left is the result from [33]; upper right is the result from [34]; lower is the result from [35]

2.2.2 Comic-like layouts, movie summarization, and other applications

Cao et al. [36] and Chu et al. [37] have reported automatic comic generation methods. These methods enable automatic creation of a grid layout for comics. The method presented by Cao et al. utilized huge amounts of scanned comic layout data using tree structures. Chu et al. used a genetic algorithm to optimize the grid layout based on image size. In Figure 2.6, the left figure shows the result of [36] and the right figure shows the result of [37]. Tanaka et al. [38] and Myodo et al. [39] have proposed comic-like layout generation methods using a tree structure. A significant number of studies have adopted tree structures, and they have shown good results. Therefore, the present study has adopted a tree data structure to develop a grid layout generator. Furthermore, Uchihashi et al. [40], Calic et al. [41], and Barnes et al. [42] have proposed movie summarization systems to edit movies easily and efficiently. These methods utilize

Fig. 2.6 Results of comic-like layout generation methods: left is the result from [36]; right are the results from [37]

grid layouts to display the summarization results. In other applications, Jacobs et al. [43] and Oliver et al. [44] have presented a document layout system and website design system, respectively, based on grid layouts.

2.3 Color support methods

Color is an effective graphic design element and can change the impressions of almost all advertising media. To fully utilize the effects of color, color harmony is significant because an appropriate combination of colors enables people to convey information efficiently and effectively. Furthermore, this effect preserves user preferences and aesthetics. Moon and Spencer [45, 46, 47] summarized a color harmony theory and quantified it as an aesthetic measure. Matsuda [48] has created a color harmony model by summarizing some forms, schemes, and relationships in a practical color coordinate system developed by the *Japan Color Research Institute*. Kobayashi [49] has proposed a color image scale that consists of three dimensions: soft–hard, warm–cool, and grayish–clear. This image scale enables the presentation of the relations between colors and their corresponding human impressions. In addition, Ou et al. [50] have developed color-science-based color emotion models by classifying color emotions for single colors. Previous studies were able to model or theorize color harmony or

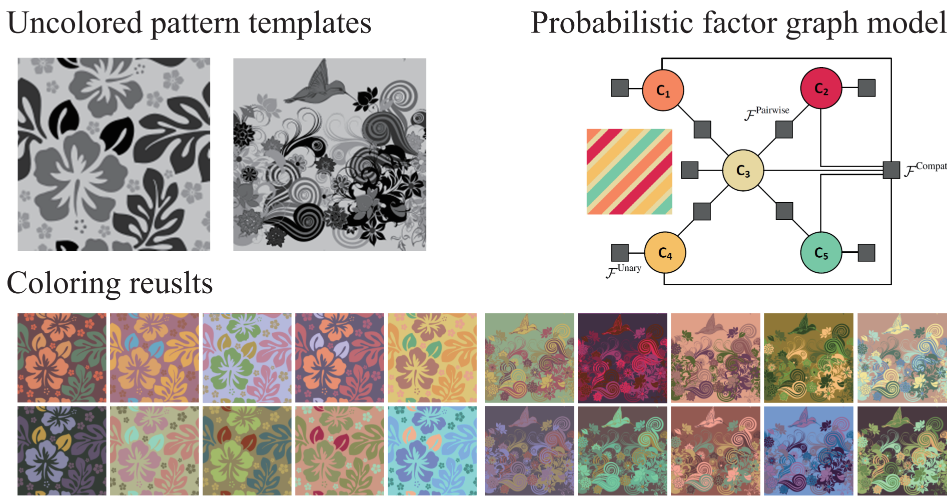


Fig. 2.7 Coloring results using the method proposed in [53]

color impressions. By referring to these outcomes, other previous studies have reported some color support methods for color transfer, color scheme creation, and other applications. This section mainly describes the color compatibility modeling methods, color transfer methods, and colorization systems.

2.3.1 Color compatibility modeling methods

O'Donovan et al. [51] and Lin et al. [52, 53] used a similar approach to investigate color compatibility or color impressions. This approach uses large color datasets or the Amazon Mechanical Turk (MTurk). Previous studies obtained large color datasets from Adobe® Kuler*2 and COLOURLovers*3. MTurk is a web service that allows the user to gather results by releasing work to specific users or the general public. By analyzing these large datasets, Donovan et al. studied color compatibility theories. Lin et al. proposed two methods: a probabilistic factor graph model for coloring and a method for extracting color themes from images using a regression model. Figure 2.7 shows the coloring results using their probabilistic factor graph model (modified figures from [53]). The method allows the user to utilize colors effectively. However, people also use an inharmonic color scheme intentionally to attract attention in advertising material. Therefore, the method in the current study also considers inharmonic

*2 https://kuler.adobe.com/create/color-wheel/ (accessed in October 2013)
*3 http://www.colourlovers.com/ (accessed in October 2013)

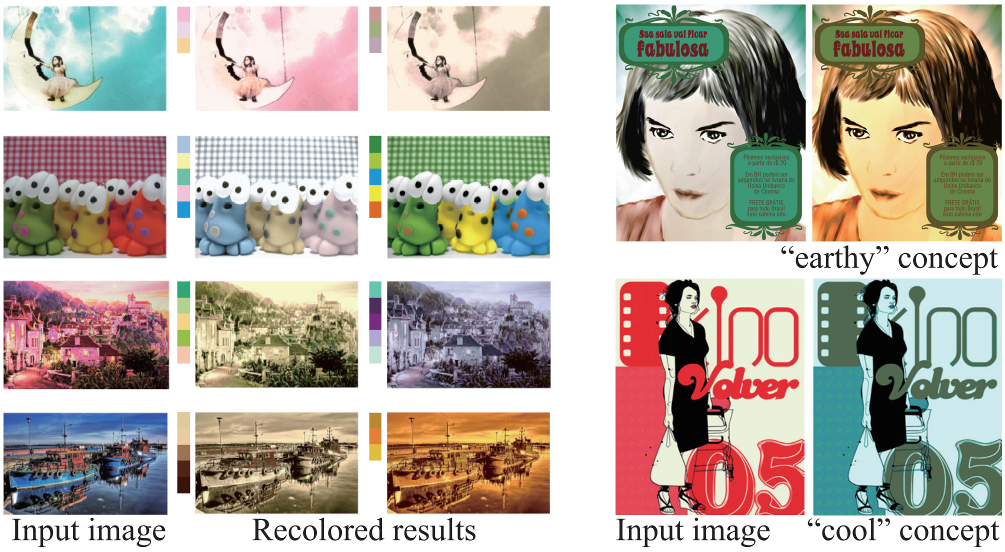


Fig. 2.8 Recolored results using proposed methods: left are the results from [59]; right are the results from [62]

color schemes.

2.3.2 Color transfer methods

Kinoshita et al. [54, 55] have developed a town-scape color planning system based on Moon and Spencer's color harmony equations. Cohen-Or et al. [56] have presented a color harmonization technique for adjusting the colors of an image by the combination of a hue histogram and Matsuda's color harmony model. In addition, Hou and Zhang [57], and Freedman and Kisilev [58] have proposed methods that enable the manipulation of colors of an image by specifying another conceptualized image. For example, to change a summer landscape image into an "Autumn" concept, the target image can change the colors using an autumn landscape image. Wang et al. [59] and Csurka et al. [60] have used a large dataset to learn concept color schemes. By utilizing these learning sets, the user can obtain good recolored photographs by specifying an appropriate color concept. Murray et al. [61, 62] have proposed an automatic color transfer method that can use photographs and illustrations. In addition, this method can control the level of the adapted concept colors. Figure 2.8 shows the results of [59, 62]. These methods allow a user to change the colors of a target image to change its impression.

2.3.3 Colorization systems

Tokumaru et al. [63, 64] proposed a color design support system based on Matsuda's color harmony model and Kobayashi's color image scale. Yamazaki and Kondo [65] have reported a method of changing a color scheme with kansei scales, which are composed of a combination of impression words and brightness. The user can easily change a color scheme via kansei scales. Gu et al. [66] and Doizaki et al. [67] have proposed a color changing method based on mood. The method of [66] does not require verbal information, and the method of [67] uses onomatopoeias to specify a mood. Inoue et al. [68, 69] and Tobitani et al. [70] have presented IEC-based color creation methods. Sugahara et al. [71], Ito et al. [72], Miki et al. [73], and Hsiao et al. [74] have proposed colorization methods for Japanese kimonos (Japanese-style clothing), t-shirts, office space design, and product color design, respectively. Figure 2.9 shows screenshots of these colorization systems. The merit of IEC-based methods is the incorporation of human evaluations into the results. The purpose of this study is to express people's kansei; thus, this study adopts an IEC method to preserve user kansei.

2.4 Studies of onomatopoeias

Onomatopoeias have been discussed in various fields of study. Some studies have reported investigative research of onomatopoeias. Other studies have proposed some applications utilizing onomatopoeias.

2.4.1 Investigative research of onomatopoeias

From the perspective of linguistic, the overall schemes and characteristics of onomatopoeias in several languages have been researched [75, 76, 77, 78]. In the schemes and characteristic of each language, there are a few differences. However, sound symbolism is highly relevant for all onomatopoeias. Japanese also has many onomatopoeias. Komatsu [79] has tried to quantify Japanese onomatopoeias from the perspective of onomatopoeia phonemes for the purpose of augmenting creative activities. Recent informatics studies have undertaken research into quantification of onomatopoeias. The details of some stud-

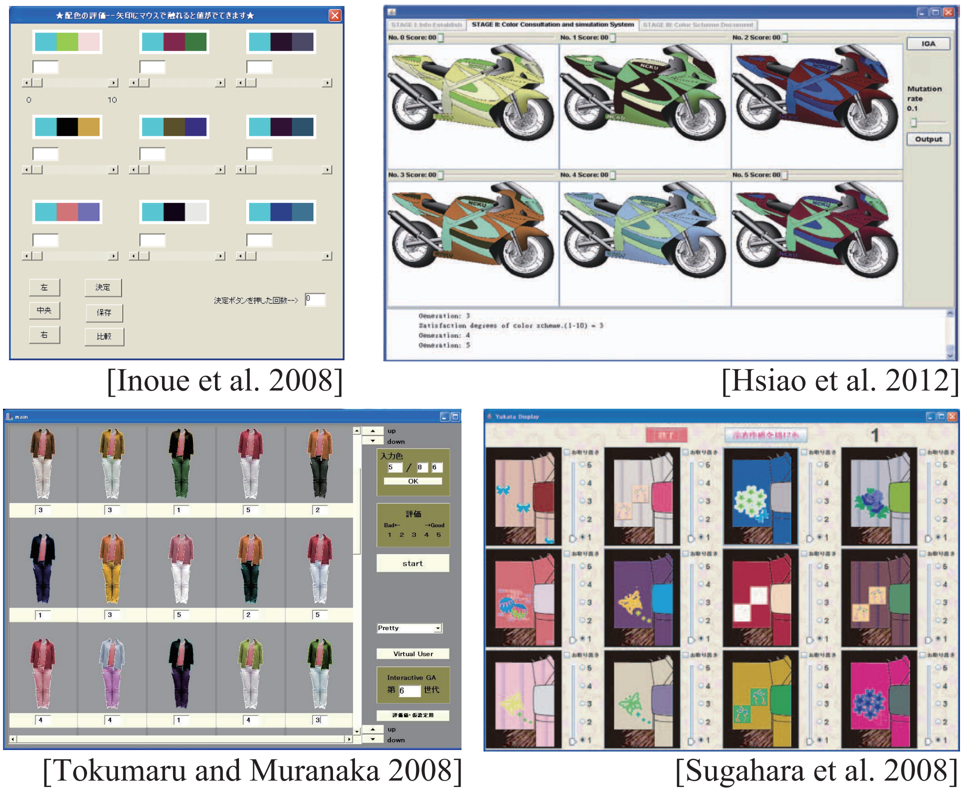


Fig. 2.9 Screenshot of each color support application

ies based on an information science approach are described in Subsection 2.4.2. In addition, other studies have conducted fieldwork that reveals the practical effectiveness of onomatopoeias. Fujino et al. [80] have developed a computerized dictionary for sport-related onomatopoeia. They have also reported that the onomatopoeias are useful for sport coaching to learn complex behavior. Udo and Takano [81] have reported that onomatopoeias facilitate communication between teachers and disabled children in a school. They guessed that the phoneme of the onomatopoeias affects the understanding of information. Furthermore, Takahashi et al. [82, 83] have conducted investigations regarding kansei information using onomatopoeias. In particular, they have proposed an investigation method for kansei information in nonverbal communication that enables the extraction of a factor space of the communicative actions using onomatopoeias. Their study has suggested that onomatopoeias may be useful in revealing kansei information.

2.4.2 Applications using onomatopoeias

Currently, onomatopoeias are attracting attention in computer science. Komatsu and Akiyama [84] have proposed an expression system of onomatopoeias for assisting intuitive user expressions. This system allows users to control the motion of a robot easily. The robot motions correspond to eight attribute vectors of onomatopoeias based on sound symbolism. This is a new input system utilizing sound symbolism of onomatopoeias. Tomoto et al. [85] have tried to visualize onomatopoeias by generating an onomatopoeia thesaurus map based on phonemic features. This map enables categorization of different types of images, such as a photograph collection of sweets based on onomatopoeias. Hayakawa et al. [86] and Watanabe et al. [87] have investigated the relationship between onomatopoeias and tactile sensations. They have created a relationship map and presented an evaluation method for tactile sensations. By focusing on this relationship, Ueda et al. [88] have proposed a medical support system for communication between Japanese patients and foreign doctors. In this system, Japanese patients input onomatopoeias to express their symptoms, and the system translates the input to the numerical values using 35 words. Kambara and Tsukada [89] have developed "Onomatopen," which is a painting system that uses onomatopoeias. This application enables users to change brush styles and effects by voice input. Watanabe and Nakamura [90] have developed "Onomatoperori," which is a search engine for cooking recipes that uses onomatopoeias. This system allows users to find desired recipes using onomatopoeias. Figure 2.10 shows examples of these applications. Kato et al. [91] have made a restaurant search application by extracting onomatopoeia from many Internet restaurant reviews. Doizaki et al. [67] have proposed an intuitive color design support system that recommends colors depending on input user onomatopoeia. This new field of research may create a better life for people in a wide variety of ways.

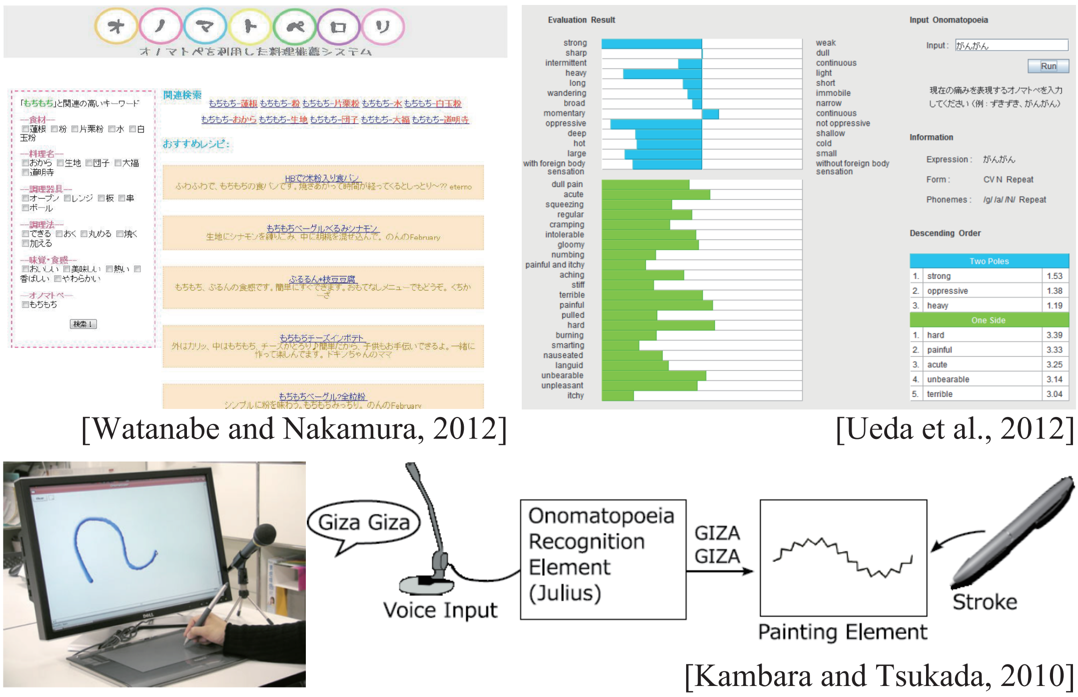


Fig. 2.10　Screenshot of onomatopoeia applications

Chapter 3

IEC-based font search method

This chapter presents a simple font search method using an interactive genetic algorithm (IGA) and similarity search (SS). Various types of fonts are used in advertising media and package designs. In addition, various choices are available when selecting suitable fonts for presentation slides or website designs. However, the existing methods used for selecting fonts become tedious as the number of fonts increases because the person selecting the fonts must first display them before making a choice. The proposed method provides a simple and effective font search process based on visual similarity. Several experiments have confirmed that the proposed method is effective for searching for a desired font, thus helping users obtain a font suitable for alphabetic (or non-alphabetic) characters. In particular, the proposed method allows users to search for a font that is suitable for some words in less than half or one-third of the time required for the user to select a font from a list.

3.1 Introduction of font search method

Advertising media and product packaging use graphics and design elements to emphasize their messages in order to convey information effectively and intuitively. One of the most important elements is the choice of fonts. In addition, people who develop websites and presentation slides must also select fonts suitable for each design. However, choosing among a large number of fonts becomes a tedious task, especially as the number of fonts increase, because the person selecting the fonts must first display each font in order to make a choice. This study describes a font selection method using an IGA and SS. The proposed

Fig. 3.1 Examples of unusual fonts

method allows users to select a font selecting by narrowing down the number of font choices from a large number of candidates. A smaller list of choices is generated by showing the person some fonts and evaluating their emotional and aesthetic response (kansei) to these fonts. On the basis of their kansei, similar fonts are quickly displayed, and the user repeats the selection process until a suitable font is found. The aim of this study is to develop a method to help users find a suitable font without having to display all choices.

3.2 Font search method based on visual similarity

The proposed method displays candidate fonts effectively and efficiently. The user evaluates candidates and selects a font similar to the desired font. The selected font is analyzed using the IGA and SS. The analysis results are used to display additional fonts for the user to evaluate. As the user continues to specify preferences, which are analyzed using the IGA and SS, the list of possible choices is gradually narrowed to candidates that are similar to the desired font. Subsection 3.2.1 describes font feature quantities (FFQs) used for the IGA and SS. The details of the IGA and SS are also described in Subsection 3.2.1.

3.2.1 Font feature quantities

The IGA and SS require FFQs to evaluate the similarities among fonts. Zalik [17] has proposed a font editing system that allows users to edit each font shape easily. Yoshida et al. [22] have proposed a font generation method using an IGA, and Nozawa et al. [25] have proposed an automatic font design system. Their methods allow users to edit the constituent elements of the fonts freely. However, it is difficult to utilize non-alphabetic characters or unusual fonts, as shown in Figure 3.1, because the user is must decide the correspondences between each constituent element of letters for each character. On the other hand, Kwan et al. [92] have used all the pixel information in an image to calculate similarity. This method requires many parameters to be used with an IGA. Therefore, these conventional methods require some manual tasks to add a new font into a database.

Generally, a font family consists of three types of styles: bold, italic, and normal. This study considers thickness and balance as crucial factors of fonts. Shibuta [93] has investigated the human impressions of some fonts. The main impression factors were darkness, balance, smoothness, and cube. This study does not deal with cube because the digitalization of cube is difficult, and cube is not a common factor for all fonts. In addition, font shape is important for determining visual similarity.

By referring to four of the factors (darkness, balance, smoothness, and font shape), the proposed method defines seven FFQs, as shown in Figure 3.2. F_1 and F_2 correspond to darkness, F_5 and F_6 correspond to balance, and F_7 corresponds to smoothness. In addition, F_3 and F_4 correspond to font shape. These FFQs are the common factors of all characters, and each FFQ is independent of the type of character.

F_1: Contrast. F_1 is the ratio of foreground (letter) pixels and background pixels, given by Eq. (3.1), where f and b are the number of foreground regions and background pixels, respectively.

$$F_1 = f/b \tag{3.1}$$

F_2: Line width. F_2 is the ratio of foreground pixels and foreground pixels after a thinning process. F_2 is given by Eq. (3.2), where f^{thin} is the number of foreground pixels after the thinning process.

$$F_2 = 1 - f/f^{thin} \tag{3.2}$$

In this calculation, a convex hull is created from a letter to calculate F_3–F_6. The shape features of the convex hull are calculated from an image moment. The image moment is defined on the gray-scale image, $I(x, y) \in [0, 1]$. The image moment of pth degree about the x-axis and qth degree about the y-axis

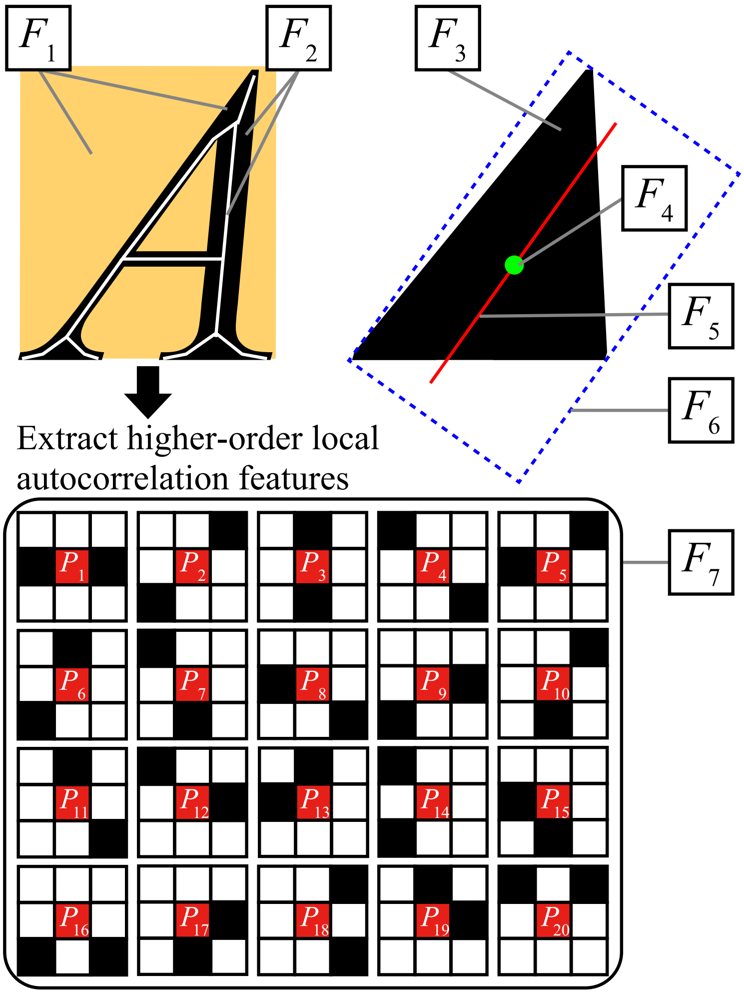


Fig. 3.2 Font Feature Quantities

is defined by Eq. (3.3).

$$M(p, q) = \sum_x \sum_y x^p y^q I(x, y) \tag{3.3}$$

F_3: Circularity. F_3 is the complexity of a convex hull given by Eq. (3.4), where S is the area and L is the boundary length using 8-connectivity contour tracing . S is equal to $M(0, 0)$.

$$F_3 = 4\pi S/L^2 \tag{3.4}$$

***F*$_4$: Center of gravity coordinate**. F_4 is the center of gravity coordinate in a convex hull given by Eq. (3.5).

$$F_4 = (x_g, y_g), \tag{3.5}$$
$$x_g = M(1,0)/M(0,0), y_g = M(0,1)/M(0,0)$$

To calculate F_5 and F_6, the following three variables are required: α, β, and γ. These variables are defined as follows [94]:

$$\alpha = \frac{M(2,0)}{M(0,0)} - x_g^2, \beta = 2\left(\frac{M(1,1)}{M(0,0)} - x_g y_g\right), \tag{3.6}$$
$$\gamma = \frac{M(0,2)}{M(0,0)} - y_g^2$$

***F*$_5$: Angle**. F_5 is the principal axis angle of inertia in a convex hull given by Eq. (3.7).

$$F_5 = \frac{1}{2}\tan^{-1}\left(\frac{\beta}{\alpha - \gamma}\right) \tag{3.7}$$

***F*$_6$: Aspect ratio**. F_6 is the ratio of a bounding rectangle along the principal axis of inertia given by Eq. (3.8).

$$F_6 = \frac{l}{l+s}, \tag{3.8}$$
$$l = \sqrt{6\left(\alpha + \gamma + \sqrt{\beta^2 + (\alpha - \gamma)^2}\right)},$$
$$s = \sqrt{6\left(\alpha + \gamma - \sqrt{\beta^2 + (\alpha - \gamma)^2}\right)}$$

Note that l and s are the long and short lengths in the bounding rectangle, respectively.
***F*$_7$: Edge patterns**. F_7 is the feature quantities of all edge regions, which are

categorized into 20 mask patterns of a 3×3 filter, given by Eq. (3.9).

$$F_7 = \{p_1, p_2, \cdots, p_{20}\}, \qquad (3.9)$$
$$p_i = \frac{c_i}{\sum_{i=1}^{20} c_i}$$

Here, p_i is the ratio of each mask pattern i in F_7 of Figure 3.2, and c_i is the amount of each mask pattern i. Scanning each pixel of the image without a thinning process detects 20 mask patterns using a 3×3 filter. In all mask patterns of Figure 3.2, the red (central) pixels indicate the current pixels. When all neighboring pixels of a current pixel are colored pixels, every mask pattern is counted as c_i. This amount of characteristic is equal to second-order higher order local autocorrelation (HLAC) features[95]. F_7 shows a histogram of edge regions.

All extracted FFQs of all installed fonts are registered in a database (DB). This registration process is performed for every letter to create DB entries. For example, the number of DB entries is 52 for the English alphabet. Note that the range of F_5 is [0, 180], and the range of the other FFQs which are the hundred fold integer values is [0, 100].

3.2.2 Similarity search (similarity function)

An SS returns results in descending order of similarity. The similarity is defined as follows:

$$s = 1.0 - \frac{\sum_{i=1}^{7} w_i d_i}{\sum_{i=1}^{7} w_i} \qquad (3.10)$$

$$if \;\; i \leq 3 \; or \; i = 6$$
$$d_i = \frac{\left|F_i^{sel} - F_i\right|}{F_i^{max} - F_i^{min}}$$
$$otherwise$$
$$d_4 = \frac{\sqrt{(x_g^{sel} - x_g)^2 + (y_g^{sel} - y_g)^2}}{\sqrt{(x_g^{max} - x_g^{min})^2 + (y_g^{max} - y_g^{min})^2}},$$

$$d_5 = \begin{cases} (180 - angle)/90 & if \; angle > 90 \\ angle/90 & otherwise \end{cases}, angle = \left|F_5^{sel} - F_5\right|,$$

$$d_7 = 1.0 - \frac{\sum_{j=1}^{20} min(p_j^{sel}, p_j)}{max(\sum_{j=1}^{20} p_j^{sel}, \sum_{j=1}^{20} p_j)}$$

Here, d_i is the difference value of F_i (ith FFQ) and F_i^{sel} (ith FFQ of user selected font), and w_i is the weight parameter of d_i. F_i^{max} and F_i^{min} are the maximum and minimum values of each FFQ in the DB. x_g^{sel} and x_g are the x-coordinates of F_4^{sel} and F_4, and x^{max} and x^{min} denote their maximum and minimum values. p_j^{sel} and p_j are the ratio of the jth mask pattern in F_7^{sel} and F_7. d_7 shows the difference value of histogram intersection[96]. w_i is the weight parameter of each FFQ; this study set $w_i = 1.0 (i = 1, 2, \ldots, 7)$. The weight parameter is related to user impressions of fonts, and this controversial point requires future work.

The SS process shows the results in descending order of similarity from all DB fonts. This similarity function is also used for the fitness function of the IGA in the proposed method.

3.2.3 Interactive genetic algorithm for font search

IGAs generate design or musical content by applying subjective user evaluation to a genetic algorithm's (GA) parameters [71, 72, 97, 98]. Hakamata et al. [99] have proposed a framework for a recommendation system using IEC. Their study attempts to incorporate a person's kansei into the GA (preferences, emotions, and intuitions). The GA computes fitness between the current solution and the optimal solution using a mathematical equation. However, user preferences are difficult to model as a mathematical equation because kansei are context-dependent parameters. In the IGA, the user participates in each fitness evaluation by communicating his or her kansei quickly and easily to the GA process.

During font selection, the IGA will allow users to display candidate fonts corresponding to their kansei. Figure 3.3 shows a flowchart of the IGA, and Table 3.1 shows the GA's basic parameters. In this study, the fitness function is synonymous with the similarity function. The similarity function is described in Subsection 3.2.2. Each process of the IGA is illustrated as follows.

STEP 1. Generate initial population

An individual consists of all FFQs (F_1–F_7) as shown in Figure 3.4. As a default

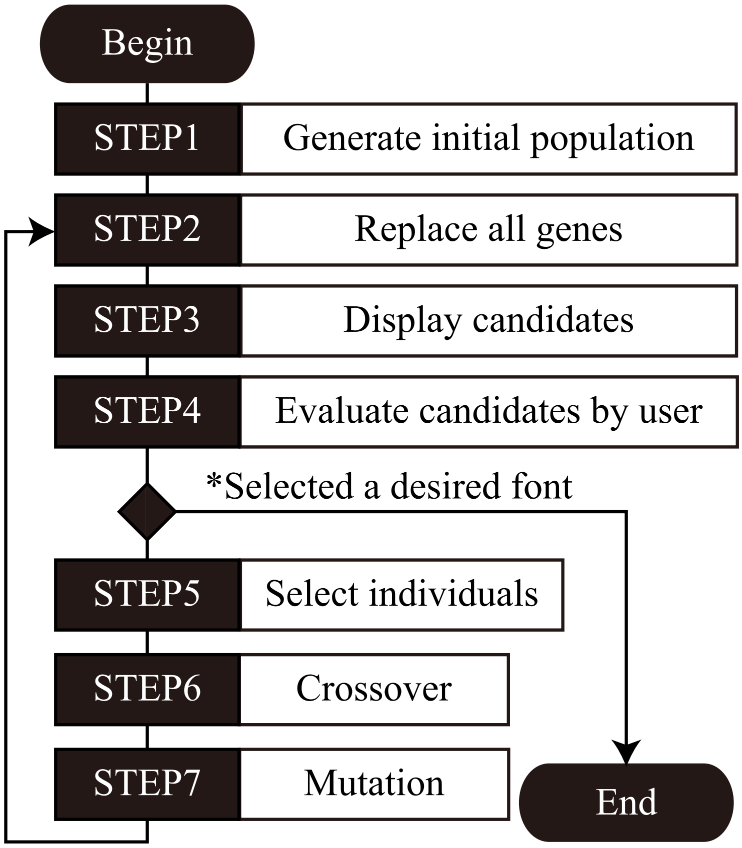


Fig. 3.3 IGA flowchart

Table 3.1 GA parameters and genetic operations

Individual number	Gene number	Selection method
9	27	Roulette Selection Elite Selection
Crossover technique	Crossover rate	Mutation rate
UniformCrossover	1.0	0.3

setting, the initial population of the FFQs is randomly collected from the DB fonts. Nakamura et al. [100] have improved the efficiency of search using user-specified random variables for the generation of initial population. To utilize user evaluations for the generation of the initial population, the IGA of the proposed method introduces two parameters; "Weight" is the average of F_1 and F_2, and "Balance" is the average of F_5 and F_6. When a user sets two initial

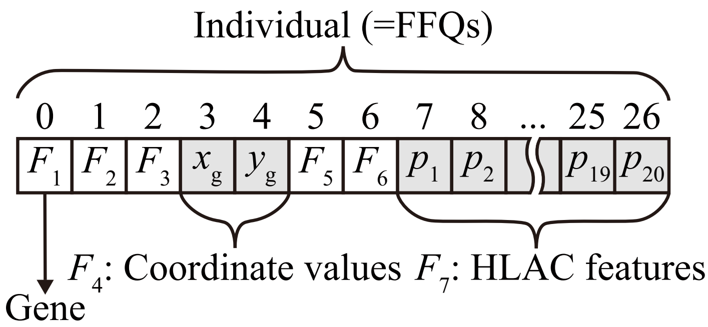


Fig. 3.4 Configuration of an individual

parameters, these parameters are reflected in the initial population. If the weight and the balance parameters are set to “Heavy” and “Bad” individually, the initial population contains bold-italic style fonts. See Appendix A.1 for further details of both initial parameters.

STEP 2. Replace all genes

Generally, IGA is used for generating design or musical content by combining parameters (genes). The IGA of the proposed method does not generate fonts but displays candidates. The method replaces each gene of an individual font with each FFQ of the DB fonts. First, the level of fitness is calculated by comparing the individual with each DB font. Then, all genes of the individual are replaced with the set of FFQs that indicate the maximum fitness among all DB fonts.

STEP 3. Display candidates

The candidate fonts are determined by each individual and are used to display a specified word. In the application, a user can enter a word spontaneously.

STEP 4. Evaluate candidates by user

The user evaluates the displayed candidates. Then, the user selects a font similar to a desired font. This method accelerates the IGA search because the user evaluates each iteration [101]. If the user finds a desired font, the process is terminated.

STEP 5. Select individuals

This IGA has adopted Elite Selection and Roulette Selection as the individual selection methods. In Elite Selection, the selected individual in STEP 4 (named Elite A) and the selected individual in a previous generation (named Elite B) become elites. In Roulette Selection, four individuals are selected stochastically based on Eq. (3.11).

$$P_i = \frac{s_i}{\sum_{i=1}^{N} s_i} \tag{3.11}$$

Here, s_i is the fitness value between Elite A and each individual i. N is the number of all individuals without Elite A. The proposed method sets $N = 8$. Note that Elite A remains a selected individual every time.

STEP 6. Crossover

Three individuals are generated randomly to increase the diversity of candidates because the IGA's population tends to converge. The number of random individuals was determined through a preliminary experiment. Furthermore, this IGA adopts the Uniform Crossover technique, in which four pairs are randomly selected from nine candidates. Each gene is exchanged at a 50% probability for every selected pairs.

STEP 7. Mutation

Mutation replaces each gene with a random value in the range of each FFQ within the DB. Note that this process is not applied to Elite A.

The above process allows users to obtain fonts that are more similar to Elite A by selecting Elite A repeatedly.

3.3 Font search application

The proposed font search method is a technique that combines the IGA and SS. This method allows the user to find a desired font based on visual similarity. This section describes the implemented font search application using the proposed method.

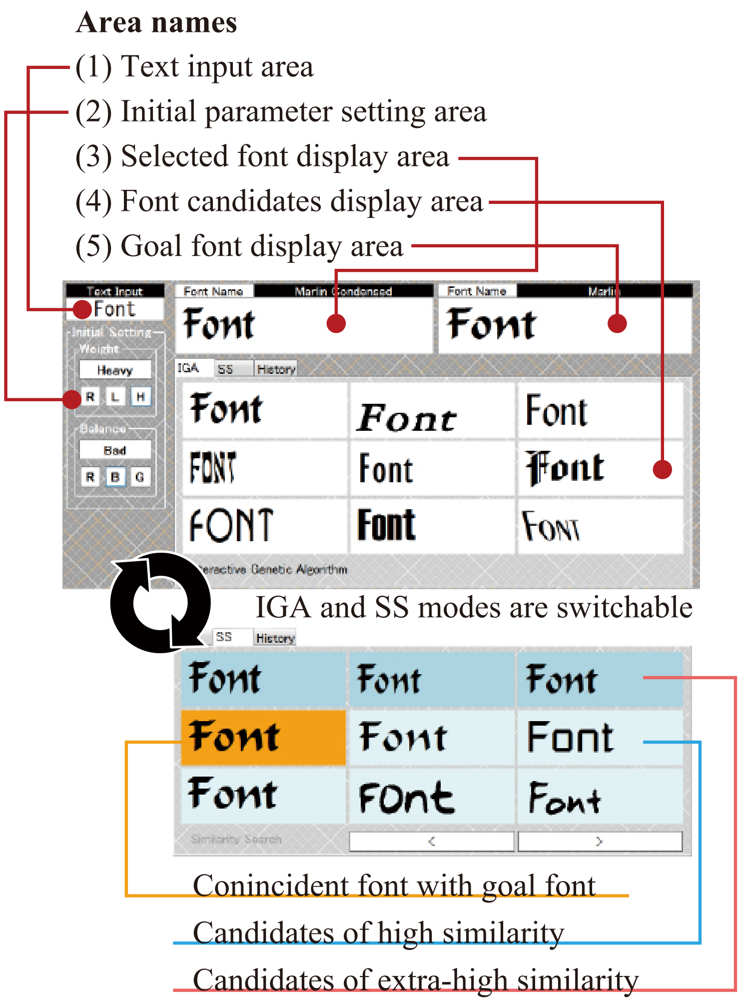


Fig. 3.5 Screenshot of font search application

3.3.1 Overview of the font search application

Figure 3.5 shows a screenshot of the implemented application and the names of each area of the application.

The implemented application consists of five areas: (1) text input area, (2) initial parameter setting area, (3) selected font display area, (4) font candidates display area and (5) goal font display area. The implemented font search application uses the previously described font search procedure.

First, the user enters a word in area (1). The user then sets two initial parameters freely in area (2) based on the user's mental image of the desired font. The user clicks on area (3), and then the initial font candidates are displayed based on the initial parameters. In this application, the user chooses a font that is similar to the desired font from the displayed candidates. The user reiterates the font selection until a desired font is obtained. In addition, this application allows the user to switch between the IGA mode and SS mode in area (4). Area (5) shows a font randomly and is used for the evaluation experiment described in Section 3.4.

3.3.2 Details of the font search application

The area (4) has three modes which are IGA mode, SS mode, and History mode. IGA mode shows font candidates that are similar to the user selected font. This mode also displays various font candidates that have different features, for example, darkness or balance factors. SS mode shows the font candidates in descending order of similarity from all DB fonts based on the user's chosen font. In this mode, the background colors of some candidates with higher similarity than a threshold are changed. This coloring effect improves the font search by preventing the search of the fonts which have the lower similarity. History mode shows the fonts that the user has selected previously. Note that this mode was not utilized for this study's evaluation experiment.

SS mode changes the background colors of the results to increase visibility. The range of the coloring threshold was determined by the results of a preliminary experiment. All participants of the preliminary experiment evaluated font candidates using SS mode. Then, they selected a suitably similar candidate font. In other words, this process determined the user acceptance threshold for visual similarity. When the participant chooses a font, the application stores the similarity value between their chosen font and a goal font. Note that a goal font is generated randomly; the target letters are 20 types of letters that were used in the evaluation experiment described in Section 3.4. There were five participants in the preliminary evaluation experiment. Each participant conducted the experiment two times per letter. The average minimum value of similarity for each letter was 0.910, and the average similarity when a similar font was not among the candidates was 0.954. From these results, the background color was decided. The lower portion of Figure 3.5 shows an example of the changing background colors depending on each similarity. The background color is set to light blue when the similarity value is 0.95 or higher, and the background is set to light cyan color when the range of similarity is between 0.91 and less than 0.95.

Existing keyword searches for fonts narrow the number of font candidates by specifying the font styles and font features. The existing methods tend to search a local font space because the search space is only within a specified font category. General users may not possess sufficient knowledge regarding font styles and font features; thus, it is not easy for them to enter appropriate keywords in existing keyword searches. In particular, when the user's desired font is not clear, it is difficult to use these keyword searches. A straightforward solution is simply to select from a list of fonts.

The IGA supports global and local searches simultaneously. The role of the global search shows various types of font candidates, and the local search allows users to narrow down the number of font candidates on the basis of user evaluation. SS strongly supports local search based on visual similarity. Therefore, users do not require expert knowledge of fonts. The combined use of the IGA and SS makes efficient font search possible because this method supports both global search and local search simultaneously. With the proposed font search method, it may be possible to find a desired font faster and easier than by selecting from a list of fonts.

3.4 Experimental evaluation of font search method

The proposed method enables searching for a desired font based on mental image that the user possesses. It is possible that determining the user's desired font is difficult for novice users because the desired font is often unclear in the user's mind. Furthermore, the user may change the desired font frequently during the font search. Thus, it is not possible to evaluate whether the user can actually obtain the desired font.

This study conducted two experiments: an objective evaluation experiment (Experiment 1) and a subjective evaluation experiment (Experiment 2). Experiment 1 investigated the effectiveness of the proposed font search method under the condition that a goal font was determined randomly. This experiment permitted objective evaluation even though the process was different from the applications's practical use. This experiment was conducted to verify whether the user can narrow the number of font candidates effectively rather than to evaluate performance. Experiment 2 validates the effectiveness of the proposed method from a subjective perspective under the condition of normal practical use. This experiment enabled us to evaluate the merit of the proposed method.

3.4.1 Experiment 1 details

The goal of Experiment 1 was to investigate the effectiveness of the font search relative to obtaining a goal font. When the participant clicked area (5) in Figure 3.5, a goal font was displayed randomly. The task of Experiment 1 was to find this goal font via the application shown in Figure 3.5. The participant repeated the selection of a font that closely resembles the goal font using the IGA or SS. If the participant selected the goal font or if a total number of displayed candidates reached a specified number, the experiment terminated. Here, the experiment was judged as a "success" by the application when the participant identified a goal font.

The application includes the English alphabet set and three sets of Japanese characters, i. e., katakana, hiragana, and kanji. The experiment used commercial font packaged software (FONT×FAN HYBRID, produced by Font Alliance Network) and free fonts available on the Internet. See Appendix A.2 for all fonts used. The numbers of fonts used are as follows: 1360 alphabet fonts, 370 katakana and hiragana fonts, and 250 kanji fonts. The total number of displayed candidates was specified as half the total number of candidates, and nine candidates were displayed simultaneously. Therefore, each maximum number of times that candidate fonts were displayed was 50 for alphabet fonts, 21 for katakana and hiragana fonts, and 14 for kanji fonts. It should be note that the actual number of times was 76 for the alphabet fonts; however, the experiment was set to 50 to reduce the number of tasks. This experiment adopted five target letters for each character: alphabet letters were "ABCDE", katakana characters were "アイウエオ", hiragana characters were "あいうえお", and kanji characters were "北陸先端大." The total number of experiments was 40 for each participant (two times per letter). Ten male graduate students in their 20s participated in the experiment; therefore, the total number of experimental results was 100 data for each letter. All participants received a brief explanation regarding the usage of the application prior to starting the experiment. They were instructed that they could freely switch between the IGA and SS modes.

In addition, the same participants conducted the same experiment using random search (RS) and SS to compare and evaluate the proposed method. RS

Table 3.2 Experiment 1 results

The type of characters	Method	Success	The number of steps	Similarity
Alphabet	IGA+SS	**86%**	**16.13**	**0.88**
	RS+SS	80%	18.49	0.85
Katakana	IGA+SS	69%	8.87	0.86
	RS+SS	**80%**	**7.62**	**0.87**
Hiragana	IGA+SS	**75%**	**8.13**	0.82
	RS+SS	69%	8.68	**0.85**
Kanji	IGA+SS	**70%**	**6.87**	0.85
	RS+SS	67%	6.91	0.85

displays font candidates randomly without overlapping. In this dissertation, the combination of the IGA and SS is denoted by IGA+SS, and the combination of RS and SS is denoted by RS+SS. Taking into account the order effect, two different groups were generated, and each group conducted the experiment in different order.

3.4.2 Experiment 1 results and discussion

The evaluation indexes of Experiment 1 were success rate, number of steps, and similarity. Table 3.2 shows the results of Experiment 1.

Note that all values are the averages of the results from the 10 participants. The bold values show the best results from each of the compared methods. The success rate indicates the rate of experiments judged as "success" for all experiments. Here, the application judged each experiment as a "success" when the participant found a goal font before the number of steps reached a maximum threshold. The number of steps shows the average values for successful cases. The similarity values show the average similarity for failed cases.

If half of the number of candidates were displayed randomly without repetition, the probability of finding a goal font was 50%. Note that the probability was approximately 33% for the alphabet fonts. As shown in Table 3.2, the minimum success rate value for all results was 67%. In addition, all success rate results for the proposed method were mostly over 70%. The success rate results and the number of steps indicate that IGA+SS was better than RS+SS, with the exception of the katakana fonts. It is considered that the lower katakana results are due to the diversity of the font search space. The IGA enables us to increase the randomness of search by setting a higher mutation ratio. After setting an appropriate mutation ratio, it was expected that the search performance of IGA+SS would the same or higher than RS+SS. IGA+SS enabled identification of a goal font in 16 steps for the alphabet fonts, and for the Japanese characters, the number of steps was less than nine. The similarity results were over 0.82; thus, the users were able to obtain a font that closely resembled a goal font.

Two main reasons for these results are as follows.

- The proposed method is capable of responding to differences in user criteria when judging visual similarity.
- The proposed method allows users to find desired fonts by judging only the visual similarity of fonts.

In the solution using the visual similarity of fonts, the controversial issue is associated with the factors that are related to user criterion for visual similarity. In other words, it is important to know what factors have been satisfied. The IGA can respond to differences in user criteria when judging visual similarity because this algorithm utilizes subjective user evaluations. Furthermore, the IGA keeps the FFQs of the user's chosen font candidate, and various types of fonts are displayed at the same time, such as slightly different fonts and some quite different fonts. Some slightly different fonts are generated by individual selection and crossover processes, and some different fonts are generated by a mutation process. These effects helped the participants to find a desired font without awareness of this controversial issue.

3.4.3 Experiment 2 details

The goal of Experiment 2 was to investigate the effectiveness of the font search under the condition of practical use. In this experiment, the participants viewed some words, and then they selected a suitable font to represent the meaning of each word. This contributes to validation of the effectiveness of the main purpose of this study because the goal fonts are unclear. If the participant judged that their chosen font was a suitable for the target word or if a total number of displayed reached a specified threshold, the experiment terminated.

The participant evaluated font satisfaction in the range [0, 100] at the end of each experimental task. Note that all participants knew that a satisfaction score of 50 indicates a compoundable criterion.

Here it is assumed that the results of the number of steps from Experiment 1 are the steps that are required to find a desired font. Each maximum number of displayed candidates was set to 17 for alphabet fonts, nine for hiragana and katakana fonts, and seven for kanji fonts. Six English words, each having an antonym, were adopted for this experiment. Japanese words having the same meaning as the English words were adopted for hiragana, katakana, and kanji. There were 24 adopted words in total: "Soft, Hard, Hot, Cold, Quick, Slow" for alphabet fonts; "やわやわ, かちかち, ほかほか, ひやひや, すいすい, のろのろ" for hiragana fonts; "ヤワヤワ, カチカチ, ホカホカ, ヒヤヒヤ, スイスイ, ノロノロ" for katakana fonts; and "柔, 硬, 温, 冷, 早, 遅" for kanji fonts. The experiment was performed once for each word; therefore, the total number of experiments was 24. The DB fonts and the number of participants were the same as Experiment 1. The total number of experimental results was 60 data for each character because the 10 participants evaluated six words.

It was expected that the proposed method would enable participants to obtain an appropriate font quicker than simple selection from a list of fonts. By assuming the use of a list of fonts, the implemented simulator calculated the numbers of steps required. The simulation was performed under the following conditions.

Condition 1
: The simulator stores the number of steps when a goal font is found under the condition of displaying nine fonts randomly without repetition.

Condition 2
: The simulator stores the number of steps when either a goal font or a similar font is found under Condition 1.

Note that the goal fonts of this simulation were the participants' chosen fonts from Experiment 2. The definition of similar fonts was determined by referring to the preliminary experimental results discussed in Subsection 3.3.2. The results indicate the participants' acknowledged similarity at similarity scores above 0.954. This simulator calculated all similarities between a goal font and each DB font, and the fonts with similarity scores above 0.954 were defined as similar fonts.

Fig. 3.6 Font examples from Experiment 2

3.4.4 Experiment 2 results and discussion

The evaluation indexes of Experiment 2 were satisfaction and number of steps. Table 3.3 shows the results of Experiment 2.

Note that the values for satisfaction and number of steps are the average values. The simulation results show the averages of 100 iterations under both conditions. Figure 3.6 shows examples of the fonts from Experiment 2.

As shown in Table 3.3, it was confirmed that the participants were able to find a suitable font for each word with high satisfaction, because the minimum satisfaction value of an “average” item (shown in bold) was 74. Figure 3.6 also shows good results. The results for the number of steps for an “average” item was approximately 13 for alphabet fonts, approximately seven for hiragana and katakana fonts, and approximately five for kanji fonts. The simulation results of Condition 1 show the number of steps required to present half of all the DB fonts. The simulation results of Condition 2 show approximately three times as many values as the results for the proposed method for the alphabet and approximately twice as many values for Japanese characters. Therefore, the proposed method allows users to search for a font that is suitable for some words in less than half or one-third the time required for the user to select a font from a font list.

3.5 Analysis and discussion of font search space

The results of the above two experimental evaluations indicated the effectiveness of the proposed method. This section describes the analysis of the font search space and presents a discussion to investigate the proposed method in further detail. The proposed method searches fonts using FFQs based on visual similarity. All DB fonts are defined as FFQs; therefore, multivariate data (FFQs) and the visual similarity given by Eq. (3.10) can represent a font search space. The analysis of this study uses Isomap [102] for the visualization of the font search space. Isomap, which is a dimensionality reduction technique, translates the font search space to low-dimensional space. All DB fonts from this study were categorized into seven styles from the supplemental list of fonts in the commercial font package. Hence, the Isomap neighborhood parameter setting was set to size $k = 7$, and the number of dimensions was $d = 2$. The analysis targets were hiragana and katakana fonts because the numbers of these fonts were the same. Two Isomaps use each FFQ data set for "あ" and "ア." Figure 3.7 shows the results of each Isomap.

Figure 3.7(a) is the result of "あ" in hiragana. Figure 3.7(b) is the result of "ア" in katakana. In each figure, the clusters are colored arbitrarily; seven examples of letters are from one of the fonts included in each cluster. The ellipses indicate the results after all clusters were grouped under the condition that each shortest Euclidean distance between every pair of clusters is less than or equal to 0.15. Note that the x-axis and y-axis of the Isomap are each dimensional axis after the dimension reduction process.

The results presented in Figure 3.7 indicate that Figure 3.7(b) has many isolated clusters when compared to Figure 3.7(a). It is believed that the number of isolated clusters relates to the search performance of the proposed method because RS+SS was superior to IGA+SS for katakana in Experiment 1. One of the features of the IGA is the premature convergence to local optima. When a font search space possesses many isolated clusters, it is possible that the IGA search will converge to the local optima in a current cluster. This feature prevents the searching of other clusters. There are some solutions to avoid this problem. For example, it may be possible to avoid this problem by increasing the number of DB fonts for interpolation between each cluster, improving the IGA, and adjusting the GA's parameters. The proposed method is effective in the case that the number of the isolated clusters is small.

3.6 Conclusion of font search method

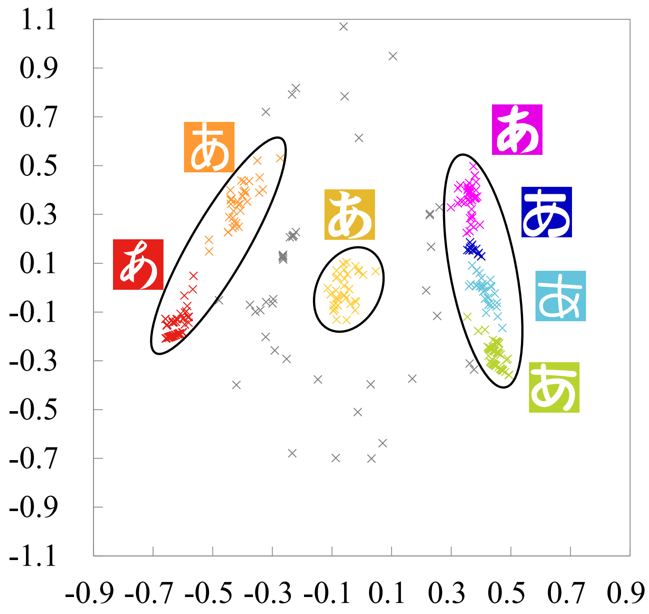
The aim of this study was to construct a method to search for a desired font easily and effectively. To accomplish this goal, this study have proposed a font search method based on visual similarity. The proposed method consists of an IGA and SS. The method allows users to find a desired font even when the desired font is unclear. Conventional methods use many tags and keywords for font search. These methods require knowledge of font factors and font styles. Even if the method uses tags that represent human impressions, significant tagging or survey of human impressions are necessary. In contrast, the proposed method enables the addition of new fonts easily using automatic extraction of FFQs. Therefore, it does not require any manual tasks.

In a simple selection from a list of fonts, the person must first display each of the fonts. Then, they must make a selection. When half of the fonts are displayed, the probability that the person can obtain a desired font is 50%. Two experimental evaluations were conducted to evaluate the proposed method. The first experimental results show that the probability that the user can obtain a desired font is approximately 70%, and the number of steps in the proposed method is less than the case of simple selection. The second experimental results show that the average satisfaction score is over 75. It is considered that even when a user's desired font is unclear, the user can obtain their desired font. In a comparison of all simulation results, it was confirmed that the proposed method allows users to search for a font that is suitable for some words in less than half to one-third of the time required for the user selects a font from a font list. In addition, the proposed method can support Japanese characters because FFQs are independent of character type.

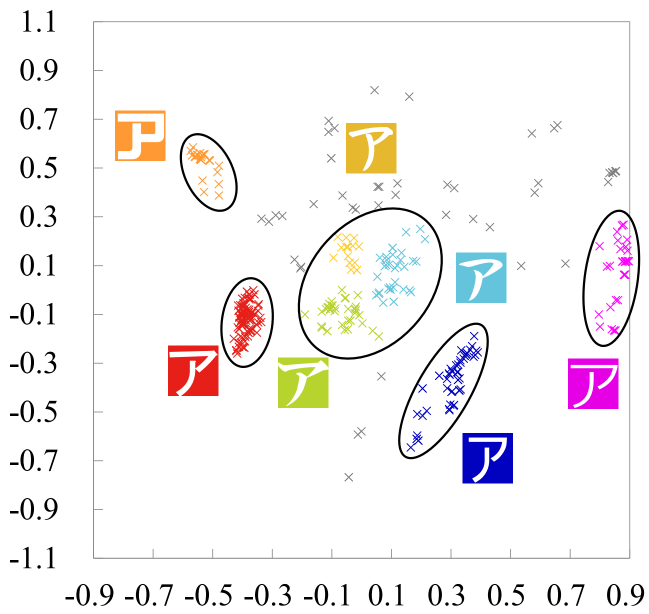
Through the analysis of the font search space, it is considered that the performance of the proposed method is relative to the distribution of font styles on the basis of visual similarity. Increasing the number of DB fonts for interpolation between each cluster, improving the IGA, and adjusting the GA's parameters may provide good solutions to improve the proposed method. Furthermore, redefining FFQs via surveys of human impressions of fonts may be effective to improve the performance of the proposed method. Future work will develop the best font search method based on user kansei by analyzing human impressions of fonts using FFQs.

Table 3.3 Experiment 2 results

Target letter	Soft	ヤワヤワ	やわやわ	柔
Satisfaction	77.00	80.00	76.50	68.00
The number of steps	12.30	6.90	6.90	5.60
Condition 1	76.83	21.25	20.23	14.40
Condition 2	42.61	14.52	14.93	11.49
Target letter	Hard	カチカチ	かちかち	硬
Satisfaction	83.30	86.00	67.70	82.50
The number of steps	11.90	6.90	8.20	5.10
Condition 1	74.52	21.31	21.61	14.30
Condition 2	12.61	18.23	15.87	7.02
Target letter	Hot	ホカホカ	ほかほか	温
Satisfaction	77.00	78.00	81.70	77.30
The number of steps	14.00	6.90	7.10	4.80
Condition 1	72.72	21.92	21.03	14.14
Condition 2	16.76	16.42	14.45	12.19
Target letter	Cold	ヒヤヒヤ	ひやひや	冷
Satisfaction	81.80	67.00	70.80	83.00
The number of steps	12.30	8.40	7.50	5.20
Condition 1	80.73	21.20	21.14	13.78
Condition 2	60.57	18.74	15.57	12.63
Target letter	Quick	スイスイ	すいすい	早
Satisfaction	83.50	72.00	67.50	76.50
The number of steps	13.60	7.80	8.30	5.80
Condition 1	76.65	20.58	21.78	14.11
Condition 2	61.33	16.25	15.11	12.68
Target letter	Slow	ノロノロ	のろのろ	遅
Satisfaction	79.00	76.00	80.80	67.20
The number of steps	12.90	7.80	7.70	5.30
Condition 1	76.22	21.29	20.76	15.48
Condition 2	55.64	14.01	19.80	12.06
Average	Alphabet	Katakana	Hiragana	Kanji
Satisfaction	80.27	76.50	74.17	75.75
The number of steps	12.83	7.45	7.62	5.30
Condition 1	76.28	21.26	21.09	14.37
Condition 2	41.59	16.36	15.95	11.34



(a) Hiragana ”あ”



(b) Katakana ”ア”

Fig. 3.7 Isomap results

Chapter 4

IEC-based grid layout generation method

This chapter presents an interactive grid layout generation method using an IEC. A grid layout is a basic and simple layout; however, generating the layout becomes tedious as the number of grids increases. The proposed grid layout generation method allows users to obtain a favorite grid layout easily and quickly with just a few operations. A collage image generating application using the proposed grid layout generation method is implemented to verify the effectiveness of the method. Several experimental evaluations utilizing this application have confirmed that the proposed grid layout generation method enables novice users to produce their desired grid layouts easily in less than 40 seconds. A comparison involving Japanese and Australian students, confirmed that the proposed layout method is useful for wide variety of people. In addition, it is considered that the fitness function based on visual features is effective for the proposed method.

4.1 Introduction of grid layout generation method

Since the 1990s, the generalization of desktop publishing has provided an environment for creating digital content such as posters, websites, and documents. When people create digital content, they must select or create appropriate design elements (layout, color schemes, images, fonts, and letters), and then they must combine these elements appropriately. There are a large number of possible candidates for each design element; therefore, the selection of the best candidates requires significant work. The work required to select or create elements, and the vast number of possible combinations of design elements makes it difficult to create digital content. This is especially true for novices. To resolve this issue, previous studies have reported support systems for creating photo collages or websites [31, 32, 33, 34, 35, 39, 43, 44]. These methods enable creation of digital contents easily; however, it is difficult for the output to reflect user kansei (preference and aesthetic) because these methods have adopted automatic or random techniques. This limitation prevents the creation of various and unique digital content based on individual kansei. This study focuses on layout, which is an essential design element for photo collages or websites. The aim of this study is to overcome the above limitation regarding kansei. In particular, the target of the study is a grid layout. Grid layout has been selected due to its relevance to various types of graphic design.

The grid layout is a basic and simple layout that is often used for posters and websites. However, making a grid layout manually is difficult for novices when they have no concrete idea of the end product. In addition, making a grid layout becomes tedious work as the number of grids increases. A straightforward solution is to utilize layout templates; however, it would be necessary to create a great many templates to satisfy user requests. To solve this problem, this study proposes a grid layout generator using IEC, an evolutionary algorithm that uses human evaluations and has a feature for narrowing the search space. Previous studies have utilized IEC to support several graphic designs [103, 104, 105, 106, 107, 108, 109]. By adopting IEC, the proposed method allows users to find their ideal grid layout by narrowing the displayed candidates easily, effectively, and quickly. Even when the user has no concrete idea of the final version, they can find a favorite grid layout from the candidates.

4.2 IEC for grid layout generation

This section illustrates IEC using the proposed method. In particular, the following sections describe the data structure and the IEC-based algorithm for grid layout generation.

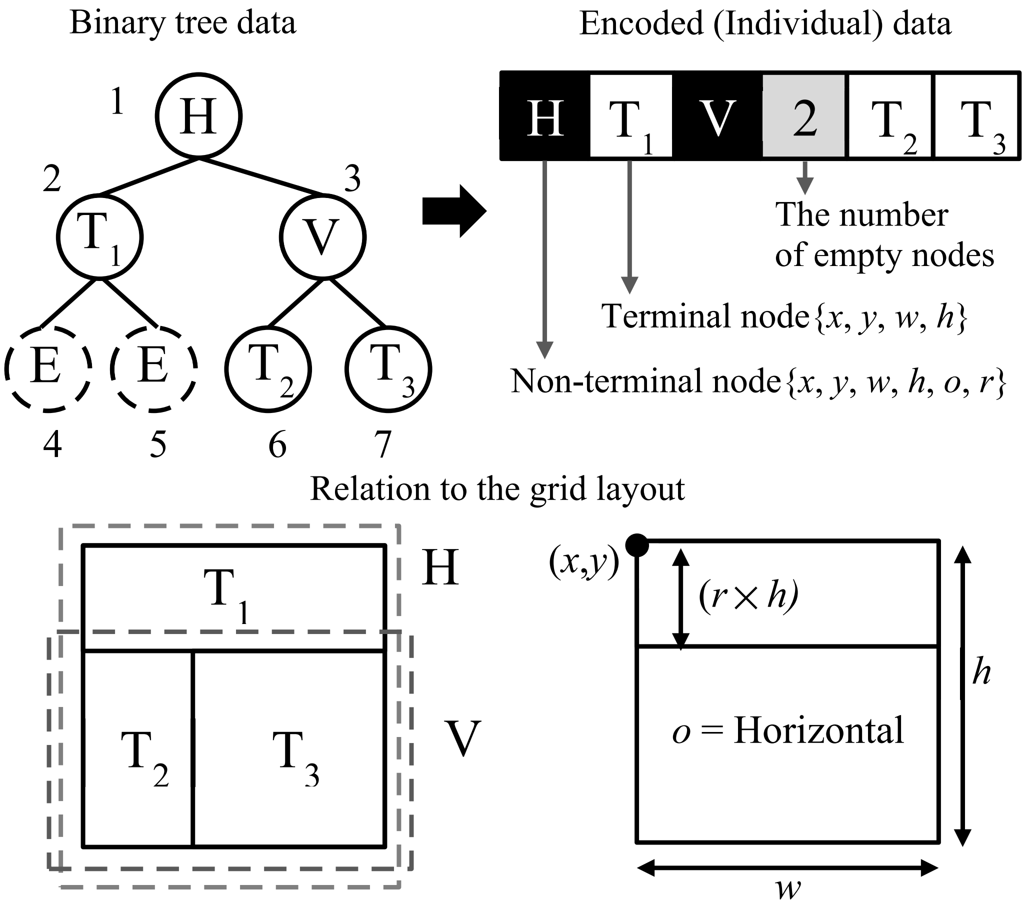


Fig. 4.1 Example of the encoded data

4.2.1 Data structure

Previous studies have adopted a tree data structure [31, 32, 36, 39] because a grid layout has a recursive structure. Atkins and Xiao et al. used a binary tree [31, 32]. The binary tree can generate various types of grid layout candidates by exchanging data.

However, general tree structure often leads to the difficulty in debugging, particularly as the tree gets deeper. Therefore, the tree data structure of the proposed method is encoded as a normal array. Figure 4.1 shows an example of the encoded data.

The top left of Figure 4.1 shows an example of a binary tree. "H" and "V" are non-terminal nodes that have four data: the location (x, y), the size (w, h), the split orientation o (here “H” is horizontal, “V” is vertical), and the splitting ratio r. “T_i” denotes the ith terminal node, which has two data: location (x, y) and size (w, h). “E” is an empty node. The top right of Figure 4.1 is the encoded array data. The array data consists of non-terminal nodes, terminal nodes, and information about the number of empty nodes. This number is used to maintain the position data of a binary tree. When checking the position of a terminal node, the position data can be calculated by all nodes and the information about the number of empty nodes. The bottom of Figure 4.1 shows an example of a grid layout generated using the encoded data.

4.2.2 Similarity of grid layout (fitness function)

IEC-based methods require user evaluation. To quantify user evaluation, IEC defines a fitness value as a numerical value. When the fitness value of a candidate is high, there is a strong possibility that the candidate is a favorite for the person. This study focuses on visual similarity, which is a general recognition of shapes and colors. This section describes the fitness function based on visual similarity used to calculate fitness values. Previous studies have defined a grid layout using the locations and sizes of each block. In human visual physiological characteristics, it is known that rods, which are concentrated at the outer edges of the retina, react to light, and the visual cortex has a detection mechanism that reacts to the line direction selectively. It is believed that brightness and line directions are the crucial visual characteristics, and they may affect the perception of visual similarity in a grid layout.

On the basis of the above information and observations, the fitness function is defined as follows. Note that similarity is synonymous with the fitness value of the interactive genetic programming (IGP). Similarity S is calculated by comparing the pixels of grid layout images in gray scale. This consists of five elements: position (f_1), contrast (f_2), orientation (f_3), size (f_4) and length (f_5). Similarity S is defined as follows:

$$S = 1.0 - \sum_{i=1}^{5} \omega_i f_i \tag{4.1}$$

where ω_i is ith weighting parameter. The range of S is [0.0, 1.0]; higher values indicate that the grid layout is quite similar to the user’s selection. The weight-

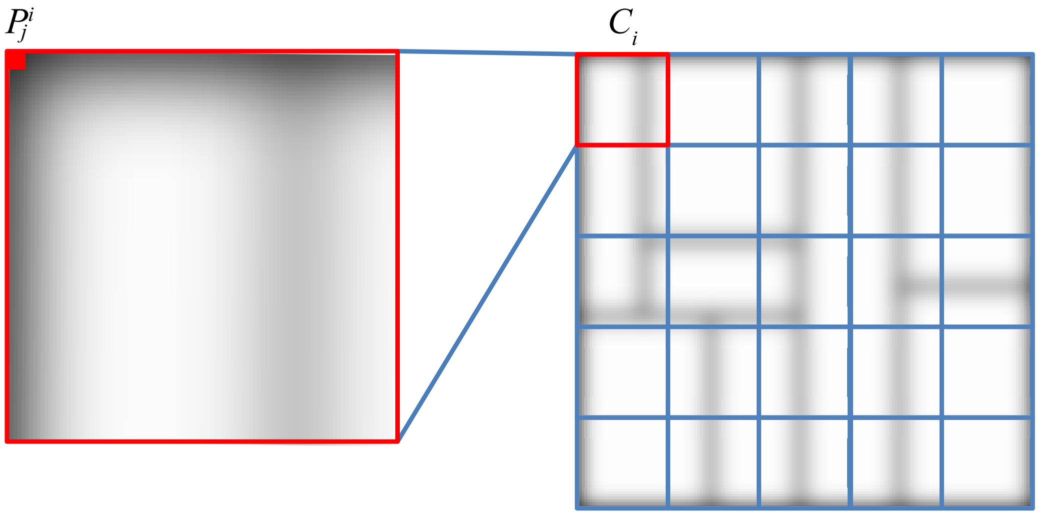


Fig. 4.2 Example of image separation

ing parameters is empirically set as $\omega_i = \{0.3, 0.4, 0.1, 0.1, 0.1\}(i = 1, 2, \cdots, 5)$. Note that $\sum_{i=1}^{5} \omega_i = 1.0$. The procedures for calculating each element f_i are provided in the following.

In the first step of the similarity calculation, a Gaussian filter is utilized for each grid layout image. Next, every image is separated, as shown in Figure 4.2. The number of cells is $N \times N$. Here, $N = 5$. The perception of the line positions may be different for each user because some mental images of the final version may be unclear. In consideration of these potential differences of perception, the grid layout image is separated into uniform cells. However, if a line of an image is on a cell splitter, the calculation result varies greatly depending on slight differences of line position. The Gaussian filter is applied to each grid layout image to reduce this difference.

f_1 is the average of the differences between a pair of cells in two different grid layouts, given by Eq. (4.2).

$$f_1 = \frac{1}{N^2} \sum_{i=1}^{N^2} |c_i^{opt} - c_i^{comp}|, \tag{4.2}$$

$$c_i = \sum_{j=1}^{wh/N^2} p_j^i$$

where c_i is the sum of pixel values in ith cell. *opt* represents the selected user grid layout, and *comp* is another grid layout candidate. p_j^i is the jth pixel value in ith cell. w and h are the width and height of an image, respectively. Note that the pixel values are normalized to $[0.0, 1.0]$.

f_2 is the difference value between two image contrast values given by Eq. (4.3). Note that each term has the same meaning as Eq. (4.2).

$$f_2 = \left| \sum_{i=1}^{N^2} c_i^{opt} - \sum_{i=1}^{N^2} c_i^{comp} \right| \tag{4.3}$$

f_3 is calculated by the number of splitters in a grid layout, given by Eq. (4.4).

$$f_3 = \left| V^{opt} - V^{comp} \right| / \left(V^{opt} + H^{opt} \right) \tag{4.4}$$

where V is the number of vertical splitters and H is the number of horizontal splitters.

f_4 is computed for each block size. In the preprocessing, all blocks of a grid layout are sorted in descending order of block size. f_4 is defined as follows:

$$f_4 = \frac{1}{2} \sum_{i=1}^{M} \left| s_i^{opt} - s_i^{comp} \right| \tag{4.5}$$
$$s_i = w_i h_i / wh$$

where s_i is the area ratio of the ith block. M is the number of blocks, and w_i and h_i are the width and height of ith block, respectively. w and h are the width and height of a grid layout, respectively.

f_5 is calculated by the line lengths with vertical and horizontal lines and is given by Eq. (4.6).

$$f_5 = \frac{\left(\frac{\left| l_V^{opt} - l_V^{comp} \right|}{h} + \frac{\left| l_H^{opt} - l_H^{comp} \right|}{w} \right)}{(V^{opt} + H^{opt})} \tag{4.6}$$

Here, l_V is the sum of line lengths of vertical splitters and l_H is the sum of line lengths of horizontal splitters.

Table 4.1 GP parameters and genetic operations

Population size	Number of elites	Selection method
18	2	Roulette Selection or Rank Selection (+ Elite Selection)
Crossover	**Crossover rate**	**Mutation rate**
One-point Crossover or Uniform Crossover	1.0	0.3

4.2.3 Interactive genetic programming for grid layout generation

The proposed method has adopted IGP as the IEC-based algorithm. IGP is an IEC method that introduces a tree data structure. Unemi [107] and Xu et al. [108] have proposed generation methods for characteristic pattern images. Jingye and Takagi [109] have used IGP to determine a composite image filter for image effect processing. However, the conventional methods are not applicable here. They cannot be used to achieve the purpose of this study. This section describes each step of the IGP process in the proposed method. The flow of this process is essentially the same as a general IEC. The GP parameters and the genetic operations are listed in Table 4.1.

STEP 1. Generate initial population

Individual data consists of some non-terminal nodes, terminal nodes, and information about the number of empty nodes. The initial population is randomly generated. First, a split orientation o and a split ratio r are set randomly as non-terminal nodes. Note that there are four ranges for random numbers for the split ratio because it is believed that the split ratio should not be heavily unbalanced: [0.1, 0.9], [0.2, 0.8], [0.3, 0.7], and [0.4, 0.6]. In the case of the split ratio $r = 0.5$, a block is divided into two equal blocks. The ranges of random numbers are different ranges by 0.1. This range setting leads to two advantages: the generation of various types of candidates and avoiding the generation of unbalanced blocks. A quarter of the initial population is generated in the range of random numbers. Next, two terminal nodes are automatically created as child nodes. Third, a terminal node randomly transforms to a non-terminal node.

Then, two terminal nodes are generated. The number of iterations of this process depends on the number of blocks in the grid layout. After generating all grid layouts, all layouts are sorted on the basis of uniformity of block sizes. For example, if all blocks of a grid layout are the same in size, that layout is displayed as the top ranked candidate.

STEP 2. Display candidates

The grid layout candidates are generated by each individual data. The displayed candidates are sorted in descending order of similarity, and the implemented application shows nine candidates simultaneously. A user can select all candidates by clicking the page button.

STEP 3. Evaluate candidates by user

The user evaluates all grid layout candidates, and selects a favorite grid layout. This method accelerates the IGP search because a user evaluates every time at each iteration [101]. If a user finds their desired grid layout, the process is terminated.

STEP 4. Select individuals

The IGP of the study adopts two basic selection methods: Roulette Selection and Rank Selection [110]. Both are stochastic selection methods. Roulette Selection uses an individual's fitness values and Rank Selection selects on the basis of the ranking of these values. In addition to these methods, this IGP has adopted Elite Selection. Here, Elite Selection was used in combination with Roulette Selection and with Rank Selection. The IGP has two elite types: Elite A, selected by user choice in STEP 3, and Elite B, selected from the individuals with high fitness values. In this process, there are three types of individuals: elite individuals; selected individuals, which are selected using each selection method; and new individuals, which are randomly generated. In this study, the number of elites, selected, and new individuals are 2, 15, and 1, respectively. Note that Elite B is not chosen as a selected individual.

STEP 5. Crossover

Crossover is an important process in IGP because it is directly related to search performance. Here, IGP has adopted two basic crossover techniques: one-point crossover and uniform crossover [110]. The general one-point crossover tech-

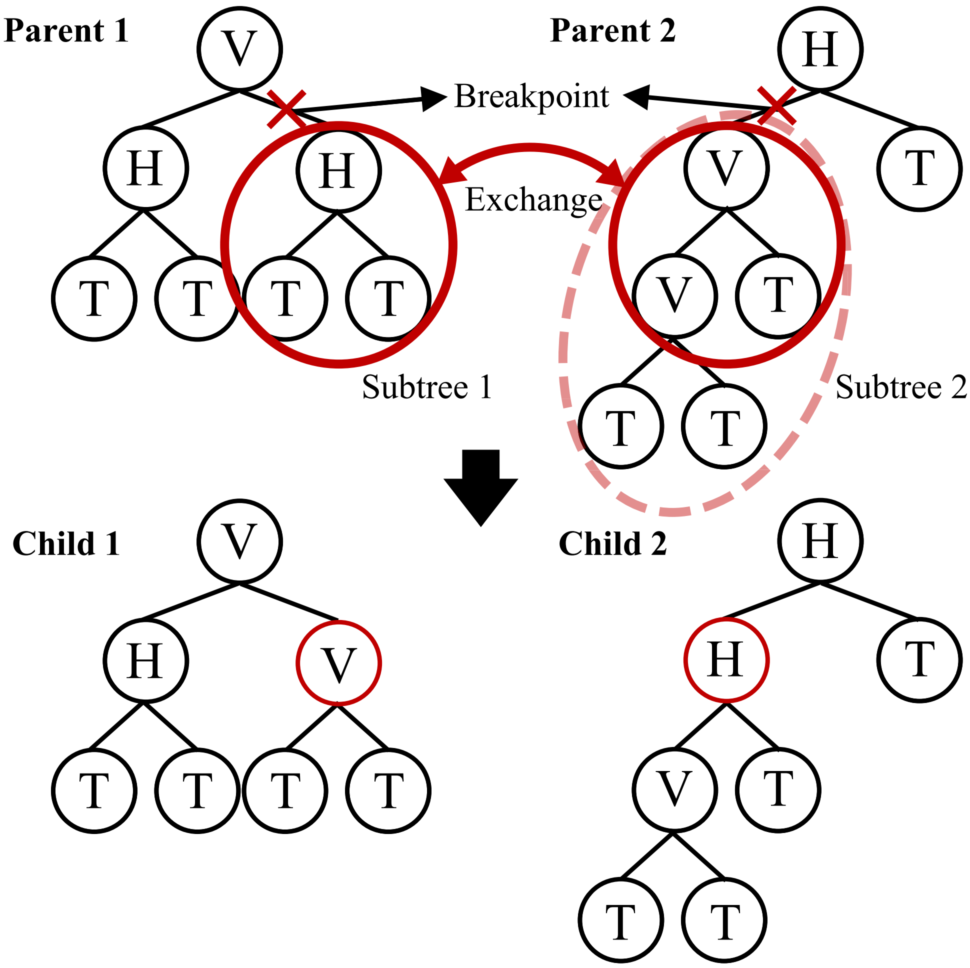


Fig. 4.3 Example of one-point crossover

nique exchanges each part of the tree data. This technique has a specific phenomenon called "bloat" [111]. "Bloat" occurs when some trees occasionally transform to deeper trees by repeating an exchange process. This leads to slow calculation; under this condition the proposed method will produce a fatal error. To overcome this problem, the IGP crossover imposes a constraint that maintains the number of non-terminal nodes in a tree. An example of one-point crossover is shown in Figure 4.3.

In this crossover, the breakpoint of a tree is created on a link between two non-terminal nodes. First, random selection determines a breakpoint in a shallower tree. In the case of Figure 4.3, Parent 1 is shallower than Parent 2; thus, the breakpoint of Parent 1 is determined randomly. Next, a breakpoint of a deeper tree is also determined randomly. Note that the number of non-terminal

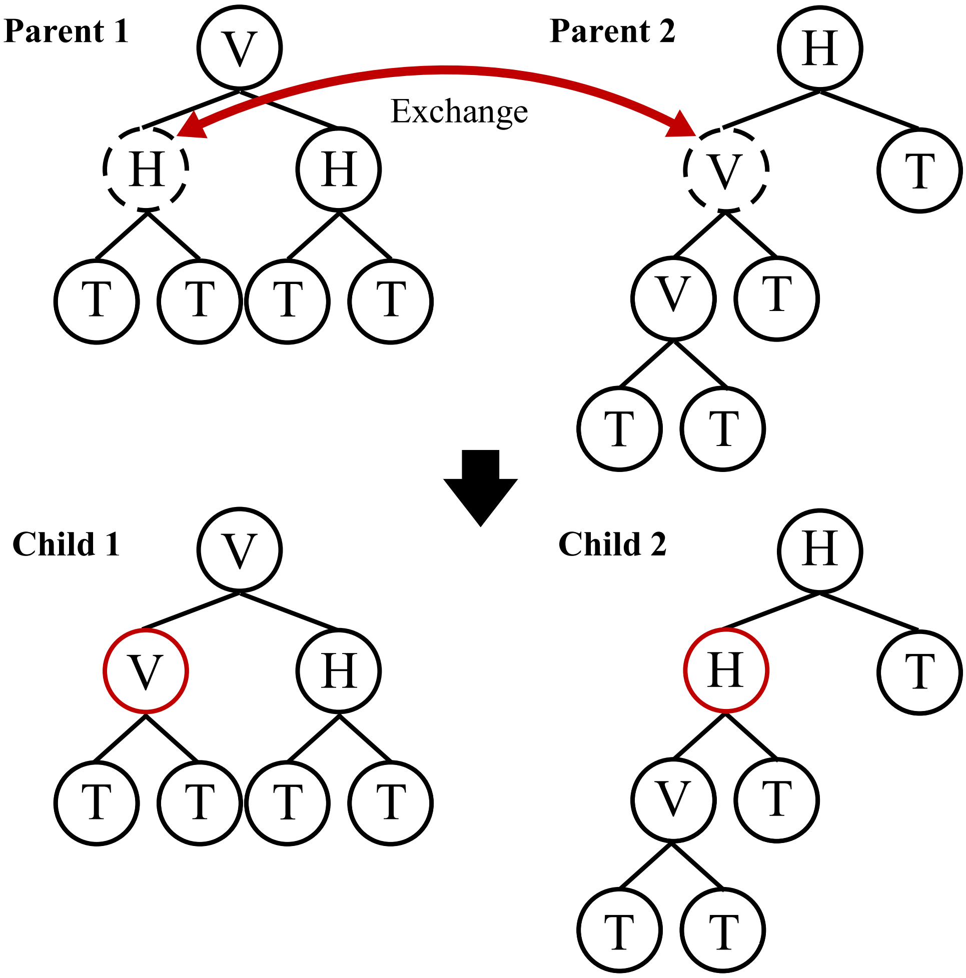


Fig. 4.4 Example of uniform crossover

nodes of the subtree must equal the number of non-terminal nodes of another tree's subtree. For example, in Figure 4.3, Subtree 2 has two non-terminal nodes. In this case, a non-terminal node that is located in a deeper position is not exchanged. Normally, Subtree 2 is the structure in the dotted line circle; however, the actual Subtree 2 is the structure in the solid line circle. Finally, two children are generated by exchanging two subtrees.

Uniform crossover is a simple process. First, one parent is compared with another. When a non-terminal node is located in the same position as that of another tree, the crossover process is applied with 50% probability. Figure 4.4 shows an example of uniform crossover.

The dotted circle of Parent 1 is located in the same position as that of Par-

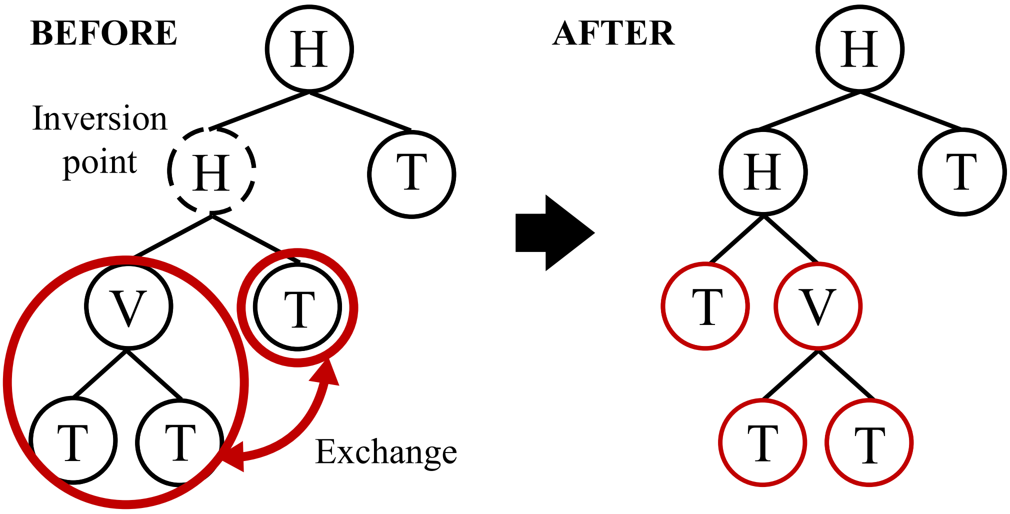


Fig. 4.5 Example of the inversion process

ent 2. Finally, two children are generated by exchanging the two non-terminal nodes (dotted circles). The crossover targets are the Elite A and some selected individuals from STEP 4. Both crossover techniques can maintain the number of non-terminal nodes in a tree data structure, thereby avoiding the "bloat" problem.

STEP 6. Mutation

The mutation process replaces each gene with a random value. The replaced items are the size (x, y), the split orientation o, and the split ratio r. The range of the random number for the split ratio is [0.1, 0.9], which is a wide range because randomness is controllable by the mutation ratio. In addition, this IGP has an inversion process that can prevent quick convergence because it has the effect of increasing the diversity of IGP. An example of the inversion process is shown in Figure 4.5.

This process swaps a part of a tree for another part of the same tree. Candidates of an inversion point are all non-terminal nodes. In the case of Figure 4.5, the dashed line circle is the inversion point, and the two subtrees, which are linked to the inversion point, are exchanged.

4.3 Grid layout generation application

This section presents a grid layout generator using the proposed IGP-based method and a photo collage application. Figure 4.6 shows screenshots of the implemented application.

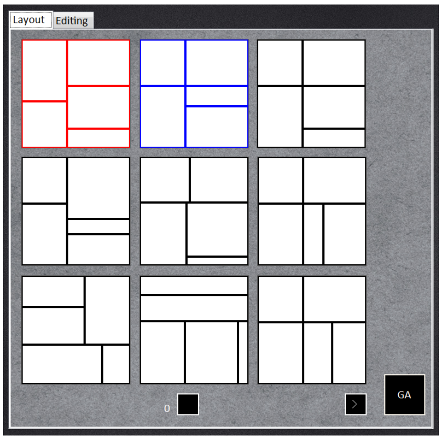
4.3.1 IEC-based grid layout generator

The grid layout generator has the following two modes.
Choice mode (Figure 4.6(a)): This mode displays nine grid layout candidates simultaneously. When a user clicks a candidate, the next candidates are generated. As the user continues to seek the best candidates, candidates are narrowed by reflecting user preference. If the user finds a good candidate, they move into the edit mode.
Edit mode (Figure 4.6(b)): This mode allows a user to change the size of the grid layout interactively. In addition, the positions and the orientations of every splitter can be changed using an interactive interface. The user can change an orientation by double-clicking on a splitter.

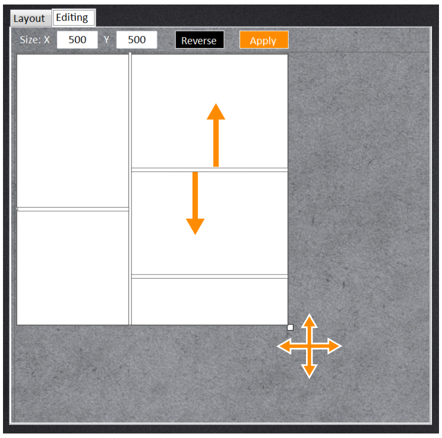
First, the user chooses a candidate that is similar to the desired gird layout. Next, the user adjusts the overall size, splitter positions, or the orientation of each splitter. The user can reselect the candidate using Choice mode after making adjustments. In this case, the current chosen candidate is the edited grid layout; thus, the user can reflect the features of the grid layout in IGP by selecting it.

4.3.2 Photo collage application

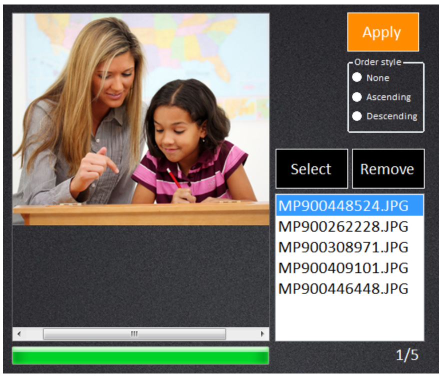
In this study, "photo collage" means an image that is filled by multiple photographs in a prescribed area. A photo collage, as seen in advertising media and social networking services, allows people to convey multiple pieces of information concurrently. Recently, photo collage software has been published for computers and smart-phones, and many people utilize such software in web logging and social networking services. In previous studies, several automatic collage generating methods have been proposed [31, 32, 33, 34, 35, 44]. These methods allow users to create a good collage even if they do not have advanced



(a) Choice mode

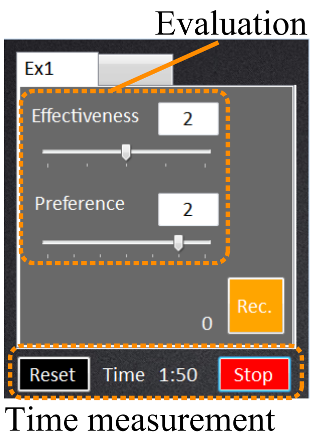


(b) Edit mode



(c) Photographs management function

(d) Main canvas



(e) Experimental evaluation function

Fig. 4.6 Screenshots of the photo collage application with the proposed grid layout generator graphic design skills and knowledge. In recent years, photo collages have been used for advertising media and social networking services; therefore, it is one of the applications considered in this study. A photo collage application was implemented to confirm the effectiveness of the layout generation method (Figure 4.6).

The application consists of the proposed grid layout generator, a photograph management function, the main canvas, and an experimental evaluation function. Figure 4.6(c) shows a screenshot of the photograph management function, Figure 4.6(d) is the canvas, and Figure 4.6(e) is the evaluation function. The photograph management function has two roles: selecting images and assigning images to a grid layout appropriately. This application utilizes a saliency map [112] and face recognition to maintain the rectangular area that is constructed from the high saliency and face areas. The assignment method is discussed in Subsection 4.3.3. When a user employs the assignment function, the result is shown in the main canvas. The main canvas is editable, and size and splitter positions can be adjusted. Furthermore, the user can change the assignment of photographs directly. The evaluation function has two roles: time measurement and evaluation of the proposed method.

4.3.3 Photo collage generating process

This section describes cropping and assignment methods for each photograph in the application. Previous studies [31, 32, 33, 34, 36, 37, 39] have adopted a saliency map and face recognition for cropping a region of each photograph. The saliency map indicates the attention areas as a gray scale image. This map is used for foreground extraction. High saliency areas, which tend to attract attention, are shown in brighter colors. Therefore, it is assumed that the brighter areas are important in a photograph. Cheng et al. [113] have proposed a fast and highly accurate histogram-based algorithm for generating a saliency map. In this study, the cropping method extracts a rectangular area from a photograph using this saliency map algorithm. Figure 4.7 shows the flow for extracting a rectangular region for the cropping process.

In this extraction process, a saliency map is generated by a histogram-based algorithm, and the high saliency areas are determined by applying a binarization process. Note that the thresholds for the binarization process are empirically set at 80, 120, and 240. A higher threshold results in a smaller high saliency

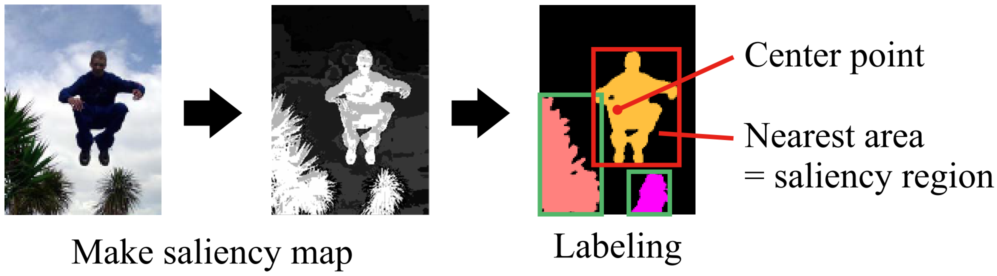


Fig. 4.7 Flow for extracting a rectangle region by a saliency map

area. This process may frequently detect several independent high saliency areas in a saliency map, such those shown in Figure 4.7. Therefore, a labeling process is performed after denoising by a median filter to detect candidates of the rectangular areas in a saliency map. It is assumed that the center object in an image is an especially important region. By calculating each Euclidean distance between the central point of the image and the central coordinate value of each candidate, a candidate that represents the minimum value is defined as the high saliency region. In this study, three different extracted rectangle areas are stored per photograph because three different thresholds are used for the binarization process.

In photographs of people, the face regions are important. Here, the important region consists of the high saliency region and face regions. Note that this study has used the default face recognition function implemented in OpenCV. The crop region is determined on the basis of this important region. To utilize photographic information maximally while maintaining this important region, this study has adopted a method that extends a region from an important region in either the vertical or horizontal direction in such a way as to fit each block shape. Figure 4.8 shows an example of the important region and the expandable regions for cropping an image.

In the left of Figure 4.8, an important region (enclosed in the green dash line) is determined by two face regions and a high saliency region (enclosed in the red solid line). The expandable areas are Rv (expandable area in the vertical direction) and Rh (expandable area in the horizontal direction) based on the important region, which are shown in the right of Figure 4.8. A crop region R is determined by uniformly expanding the important region horizontally or vertically in such a way as to fit the corresponding block shape.

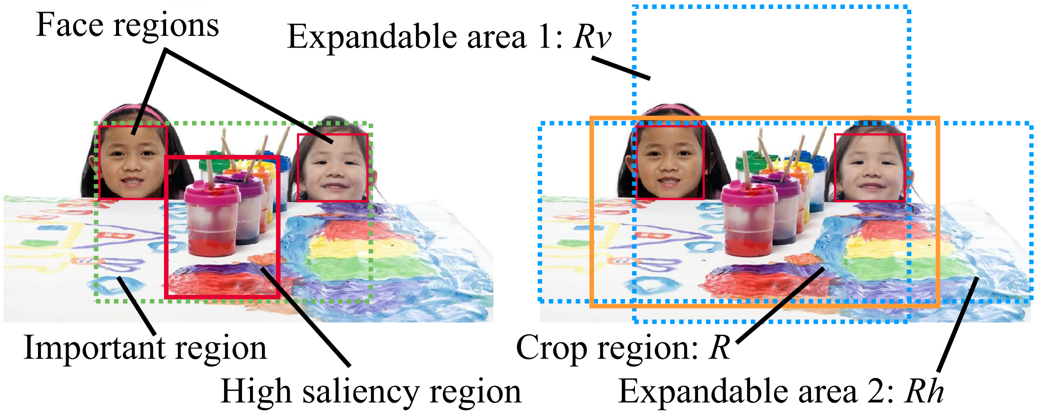


Fig. 4.8 Example of the important region and expandable regions for image cropping

This study has adopted the penalty function P from reference [39] for the assignment process. P is computed by the sizes of a crop region and two expandable regions, and is given by Eq. (4.7).

$$P = \sum_{i=1}^{N} max\left(log\left(\frac{A(Rh_i)}{A(R_i)}\right),\ log\left(\frac{A(R_i)}{A(Rv_i)}\right),\ 0\right) \tag{4.7}$$

Here, $A(R)$ is the area of crop region, and $A(Rv)$ and $A(Rh)$ are the areas of the expandable regions in the vertical and horizontal directions, respectively. Lower values indicate that the expandable region is more similar to the corresponding block shape. Thus, penalty P maintains the image information in the assignment process. If all combinations of each block and each photograph are computed, this results in slow calculation as the numbers of blocks and photographs increase. To avoid this problem, the calculation time is limited by randomly sampling $6! = 720$ combination patterns without duplication. The total limitation is $6! \times 3 = 2160$ because the binarization process uses three unique threshold values.

4.4 Experimental evaluation of grid layout generation method

This section describes an experimental evaluation. The experiment has two primary evaluation items: the user experience of the proposed grid layout generator and evaluation of generated photo collage. The effectiveness of the proposed grid layout generation method was investigated using using these two evaluation items.

4.4.1 The details of the experiment

The details of this experiment are as follows.
Subjects: Twenty graduate students participated in this experiment; 10 subjects were from a Japanese university (one female and nine males), and 10 subjects were from an Australian university (two females and eight males). Note that the students from the Japanese university are Japanese; however, the nationalities of students from the Australian university were not investigated. It should be note that not all students were Japanese. All subjects were in their 20s, with the exception one student from Australian university who was in their 30s.
Experimental equipment and environment: The experimental equipment were LCD monitors (FlexScan M1950-R, Size: 19 inch, Resolution: 1280×1024) and PCs (Intel Core i7 2.3GHz, 8GB RAM). In same case, equipment of equal performance was used. Note that the color of the LCD monitor was adjusted using the following values: color temperature, 6500K; contrast, 50; brightness, 30. The distance between each subject and the LCD monitor was not fixed. From observations, the actual distances ranged from 40 to 50 cm. To generate the photo collage, 30 images are selected from Microsoft® clip arts (15 portrait images and 15 landscape images). Note that these did not include any unpleasant photographs. Half of the Australian and Japanese students used landscape images, and the other half used portrait images. See Appendix B.1 for all images used.
Experimental evaluation items: The experimental evaluation items were the effectiveness of the proposed grid layout generator and the subject's pre-

Table 4.2 Evaluation items

Effectiveness	Preference
0 = “Not at all effective”	-3 = “Very bad”
1 = “Slightly effective”	-2 = “Bad”
2 = “Somewhat effective”	-1 = “Slightly bad”
3 = “Very effective”	0 = “Acceptable”
4 = “Extremely effective”	1 = “Slightly good”
–	2 = “Good”
–	3 = “Very good”

ferred photo collage. The range of preference was $[-3, 3]$ on a seven point rating scale. The range of effectiveness was [0, 4] on a five point rating scale. Table 4.2 shows the details of the two evaluation items. The effectiveness indicates the performance of the proposed grid layout generator. For this evaluation item, the user evaluated whether the proposed generator can display candidates that closely resembled the user's desired collage. For the preference evaluation item, all subjects were instructed that the criterion for an acceptable result was zero. Therefore, if the preference was zero or greater, the subject was able to obtain a favorite grid layout.

4.4.2 The experimental procedure

In the preliminary explanation, an explanation of the operation procedure of the implemented application was provided to the subjects. First, the subject generates their desired grid layout using the proposed grid layout generator. This experiment limited operation time to two minutes for each subject. If the subject achieved their best grid layout, the timer was stopped. The generated grid layout was used to make a photo collage. Note that the size of the grid layout was fixed at 500×500 pixels. Next, the application automatically generates a photo collage using the generated grid layout with 15 images, which were prepared beforehand. Finally, the subject evaluated the effectiveness and preference via the evaluation function shown in Figure 4.6(e).

In a previous study, subjects used an average of 13 photographs to generate a collage image [32]. In addition, it is considered that a smaller number of blocks were appropriate for this experiment because the evaluation of effectiveness was easy for the subjects. Thus, five, 10, and 15 blocks were set for creating a collage image. Note that all experimental results are summarized because there were no significant differences in the effectiveness for the comparison of landscape and portrait images from the student's t-test ($\alpha = 0.05$). The number of iterations was four with each number of blocks; thus, the total number of iterations was 12. In each task, the combination of selection methods and crossover techniques were changed. In Table 4.3, each combination of selection methods and crossover techniques is indicated as a pattern ID. Pattern 1 shows the combination of roulette selection and one-point crossover, Pattern 2 is roulette selection and uniform crossover, Pattern 3 is rank selection and one-point crossover, and Pattern 4 is rank selection and uniform crossover. The combinations were changed automatically in the experiment. All subjects were unaware of the differing combination patterns. However, the subjects were informed about operation procedures, time limitation, evaluation items, and number of iterations to generate photo collages.

4.4.3 Experimental results and discussion

In addition to these two evaluation items, three types of information were recorded: choice operation, moving operation, and change operation. "Choice operation" is the number of times that users chose candidates. "Moving operation" is the number of times that users changed the positions of the splitters, and "Change operation" is the number of times that users changed their orientations. Table 4.3 shows the experimental results, and Figure 4.9 shows some examples of the photo collages generated by the subjects.

In Table 4.3, all values are the average values obtained from 60 data. The bold fonts show the best values among all combination patterns. From these results, Pattern 1 shows good results for effectiveness and preference. Operation time, choice operation, and changing time also show good results. In addition, the results of the student's t-test ($\alpha = 0.05$) show the significant differences between each combination of Pattern 1 and the other patterns (Pattern 2 – Pattern 4) for effectiveness and preference. Significant differences were observed for operating time between Pattern 1 and Pattern 2. Hence, the

Table 4.3 Experimental results

Combination pattern ID	Pattern1	Pattern2	Pattern3	Pattern4
Effectiveness	**2.85**	2.35	2.35	2.43
Preference	**1.90**	1.15	1.03	1.10
Operation time [sec.]	**39.73**	47.23	42.60	43.12
Choice operation	**2.83**	3.48	4.40	3.47
Moving operation	**3.52**	4.18	4.20	3.82
Change operation	0.20	0.20	0.20	0.30

Fig. 4.9 Six examples of photo collages generated in the experiment

combination of roulette selection and one-point crossover was the best for the proposed grid layout generator. In the results for Pattern 1, effectiveness was 2.85, indicating “Very effective”, and preference was 1.97, indicating “Good.” In other words, the proposed method had “Very effective” performance, and the collage application could generate “Good” photo collages. The operation time was 39.73 seconds for approximately 6.5 operations (the sum of choice, moving,

Table 4.4 Results by country

Country	Japan	Australia
Effectiveness	2.70	**3.00**
Preference	1.83	**1.97**
Operation time [sec.]	**29.70**	49.77
Choice operation	**2.47**	3.20
Moving operation	4.17	**2.87**
Change operation	0.17	**0.10**

and change operations). A conventional application requires 16 minutes (average time) to generate a collage image [32]. Therefore, the proposed method is sufficiently quick. The other results showed no significant differences for all combinations. Consequently, it is reasonable to assume that either roulette selection or one-point crossover is not effective. However, in combination, the grid layout generator maintains good balance between convergence and diversity. Furthermore, the results indicate that similarity defined on the basis of visual features is effective for the proposed method.

4.4.4 Difference of effectiveness by country

This section describes the difference of effectiveness from a comparison of the experimental results for the Japanese university students and the Australian university students. Table 4.4 shows the results of the comparison for Pattern 1.

Note that the bold fonts show the best values for each evaluation item, and the underlined value is the result that is significantly different in student's t-test ($\alpha = 0.05$). All results are average values from 30 data. The comparison results shown in Table 4.4 indicate that "Operation time" was significantly different; Japanese students generated grid layouts faster than the students from the Australian university. The other items demonstrated no significant differences; however, the results for the Japanese students were lower than the result for the Australian students for "Choice operation." In contrast, the results for the Australian students were lower than the result for the Japanese students for "Moving operation". Thus, it is considered that Japanese students tend to construct a desired grid layout by generating a grid layout quickly with choice mode and heavy use of edit mode. On the other hand, Australian students tend to continue to choose candidates until they obtain a desired grid layout using choice mode. The results for operation time in Table 4.4 indicate a different between Japanese and Australian students because choice operation is required enough time to find preferred candidate. For effectiveness and preference items, the results for Japanese students and Australian students were mostly the same. Therefore, it is reasonable to conclude that the proposed grid layout generator supports global usage. In particular, Japanese students can obtain their desired grid layouts quickly. This study does not discuss gender comparison or age comparison because the number of subjects was insufficient for comparisons.

4.5 Influence of various factors on experimental results

The experimental results are influenced by the order in which the combination methods in IGP were used, the content of each photograph, and the cropping method. This section discusses the influences of various factors on the experimental results.

4.5.1 Order of combination patterns

In the experiment, the order of the combination patterns from Pattern 1 to Pattern 4 changed automatically. The user was able to use the application smoothly by repeated use. Hence, it is considered that the results for operation time may have become shorter as the combination methods changed. From the perspective of the shapes of grid layouts, the impression of grid layouts does not differ significantly because blocks are assigned to a specified rectangular area. Therefore, the preference result may have increased by repeated presentation of some grid layouts due to a mere exposure effect [114]. If this phenomenon affected the experimental evaluations, preference for Pattern 4 should be highest. However, the results for Pattern 1 were the best among the results shown in Table 4.3. Thus, Pattern 1 is most suitable for the proposed grid layout generator.

4.5.2 Influence of photographs and cropping process

The experiment used natural landscape photographs and portraits of people smiling; there were no images that would elicit an unpleasant feeling. The cropping method used a technique that is similar to conventional methods [31, 32, 33, 34, 36, 37, 39]. These conventional methods have produced good photo collages for users. It is believed that the subjects did not feel bad when using this cropping approach. This indicates a low probability of creating a poor impressions in the photo collages as a result of the cropping method. In view of the above, if the results for preference were bad, it is considered that the proposed grid layout generator would yield poor results. The preference result for Pattern 1 shown in Table 4.3 is 1.90, which indicates that the effectiveness of the proposed method is high for practical use. Even where the subject obtained a desired grid layout, there were cases in which a bad photo collage was obtained. Thus, the results of effectiveness and preference are not always coincident. It is inferred that the user can achieve a good photo collage when they obtain a desired grid layout.

4.6 Conclusion of grid layout generation method

This study has presented a grid layout generator that employs IEC and a collage image generating application that uses a grid layout generator. The proposed method consists of candidate selection using an IGP, and an interactive user interface for editing. This method allows users to generate a desired grid layout quickly and effectively, and is a new example of an IGP application. In contrast to conventional automatic or template-based generation methods, the proposed method enables users to reflect their kansei (request). Furthermore, when the user has no concrete mental image of the final version, the user can generate a desired grid layout because their mental concept is gradually clarified by repeating candidate selection. To validate the effectiveness of the proposed method, the grid layout generator was incorporated in a photo collage application to conduct an evaluation experiment. The experimental evaluations confirmed that the proposed grid layout generator provides the user with candidates effectively, and the photo collage application allows the user to compose a desired photo collage. The experimental results indicate that the best method for IGP was

Fig. 4.10 Example of collage image using 100 photographs

the combination of roulette selection and one-point crossover. Using this combination, the proposed method was able to generate a desired grid layout in less than 40 seconds with approximately 6.5 operations, which indicates that similarity based on human visual features is effective for the proposed grid layout generation method. A comparison of the experimental results for Japanese and Australian students indicated that the proposed grid layout generator supports global use. It is particularly effective for Japanese users relative to operation time. In addition, the proposed grid layout generator can treat a significant number of blocks, as is shown in Figure 4.10. However, the maximum number of usable blocks on a grid layout depends on the size of the workspace, because a grid layout cannot be generated when there is no space to construct the splitters. If users require a large number of blocks, it would be better to apply solutions that make the tree structure uniform.

Future work will determine the best grid layout generation method based on user kansei by analyzing human impressions, improving the IGP algorithm, and adjusting the IGP parameters.

Chapter 5

IEC-based color scheme search method

This chapter describes a statistics-based interactive evolutionary computation (IEC) method for color scheme search. Color schemes are utilized in an enormous range of items such as websites, clothing, advertising media, and housewares. However, people who do not have sufficient skill or knowledge of colors need to devote considerable time and effort to a create color scheme. Currently, artists' color schemes are freely available from websites. However, it is difficult for users to find an appropriate color scheme from a large data set. To overcome this problem, this study relies on a statistics-based interactive genetic algorithm (IGA). Use of this IGA is expected to reduce computing costs compared with those of conventional IEC approaches, and respect overall color scheme impressions. These contributions enable realization of the kansei-based color search system in real time. In addition, this study introduces four similarity search (SS) functions (hue, saturation, brightness, and color differences) to facilitate the convergence of a color scheme search. The combination of a statistics-based IGA and four SS functions allows users to easily and effectively find their desired color schemes.

5.1 Introduction of color scheme search method

A color scheme is a significant element in most designs. Recently, some color websites such as COLOURlovers and Adobe® Kuler are available for general use. These websites allow users to share artists' color schemes and utilize them freely. However, it is difficult for users to find their desired color schemes from a large dataset. Hence, people who do not have sufficient skills or knowledge of colors need to devote more time and effort to obtain their favorite color scheme.

In previous studies, an IEC has been applied to some color support systems for color scheme creation or color design. Existing IEC-based color schemes generating systems provide users with several suggested color schemes [68, 69, 70]. Other existing systems support color design for clothing, interior accessories, and products [71, 72, 73, 74]. An IEC-based approach gives users various color scheme candidates by changing color patterns; hence users can find their favorites among all candidates. Furthermore, this method uses some human inputs; consequently, it is possible to gradually narrow the candidates based on user kansei. Conventional IEC-based systems directly encode all color data in RGB, HSB, or L*a*b* color space; thereby, these approaches incur increasing computational costs with the number of target colors. In fact, most previous studies did not target more than three colors. Because of this limitation, a color scheme search method using the conventional IEC method typically does not handle more than three colors.

To overcome this limitation, this study adopts an IEC method based on statistics. This new approach has two advantages. First, it decreases the computing cost compared to conventional IEC-based approaches, because the proposed approach fixes the number of data; second, it maintains overall color scheme impressions. Previous studies have reported that people respond similarly to specific colors or color schemes [16, 48, 49, 50]. The common responses or impressions are related to combinations of hue, saturation, and brightness. The statistics-based approach enables the overall impressions to be changed using the statistics of a color scheme. In contrast, conventional IEC-based approaches do not take the overall color scheme impressions into account. The proposed method enables users to find a desired color based on the user's kansei.

As previously mentioned, the features of the proposed method realize the kansei-based color search system in real time. In addition, this system introduces four SS functions based on hue, saturation, brightness, and color differences. Consequently, it is expected that the combination of the proposed IEC-method and four SS functions will enable users to find their desired color schemes based on their kansei.

5.2 Statistics-based IEC method for color scheme search

This section describes a statistics-based IEC method for color scheme search. Conventional IEC-based color support systems do not consider color characteristics. Previous studies have introduced an objective function to adjust color scheme candidates based on color harmony theory [54, 55, 70, 115]. This is a good solution for the creation of harmonious color schemes, however the use of the object function becomes a hindrance when obtaining a favorite color scheme. In addition, it is difficult for novice users to take color harmonics into consideration when generating a desired color scheme.

5.2.1 Statistics data of color scheme in IEC

The proposed statistics-based IEC uses basic statistics: average values, standard deviations, or coefficient of variations in a color scheme. This study focuses on the overall color scheme impression. The impression is related to hue, saturation, and brightness. For example, when a user wants a warm color scheme, he or she will look for a reddish color scheme. This study takes into account the statistics of overall impressions for color schemes. Human perception of colors is an important factor when choosing color schemes. Generally, HSV and HLS color models are utilized for hue, saturation, and brightness values. However, these models do not take human perceptions into account. L*a*b* color space is a well-known perceptually-based color model. Color difference in L*a*b* indicates the Euclidean distance in the color space, and this distance corresponds to human perceptions. This study uses L*c*h* values, which are represented in L*a*b* color space. L*c*h* indicates brightness, saturation, and hue values respectively. Note that $c^* = \sqrt{(a^*)^2 + (b^*)^2}$, $h^* = \arctan(b^*/a^*)$, and L^* is calculated in L*a*b* color space. To consider human perception as much as possible, this study adopts the perceptually-based saturation $S = \frac{\sqrt{a^2+b^2}}{\sqrt{a^2+b^2+L^2}} \times 100\%$ reported by Lübbe [116] instead of c*. Therefore, this study adopted the average values L^*_{ave}, h^*_{ave}, S_{ave}, the coefficient variations $L^*_{C.V.}$, $S_{C.V.}$ and the standard deviation h^*_{SD}.

Table 5.1 GA parameters and genetic operations

Population size	Number of elites	Selection method
9	2	Roulette Selection Elite Selection
Crossover	Crossover rate	Mutation rate
Uniform Crossover	1.0	0.3

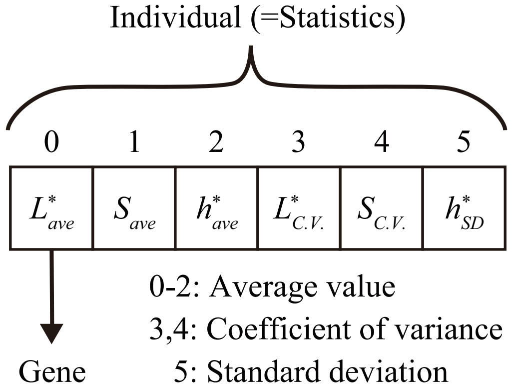


Fig. 5.1 Configuration of an individual

5.2.2 Interactive genetic algorithm for a color scheme search

This study adopts an IGA, which is a commonly used IEC method. This section describes the statistics-based IGA for a color scheme search. The statistics-based IGA processes are described in the following seven steps. GA parameters and the genetic operations are shown in Table 5.1.

STEP 1. Generate initial population

Statistics for an individual are provided in Figure 5.1. An initial population of IGA is strongly associated with IGA search performance. In this study, the search space is a dataset of color schemes; therefore, all generated individuals are color scheme data in the color scheme database (DB). The IGA used here utilizes probability distributions of each cluster to generate various candidates in the initial population. The process of generating the initial population is as follows. The first process uses multidimensional scaling (MDS) for the color scheme DB. Then the color scheme DB is visualized as a 2D map, as shown in Figure 5.2.

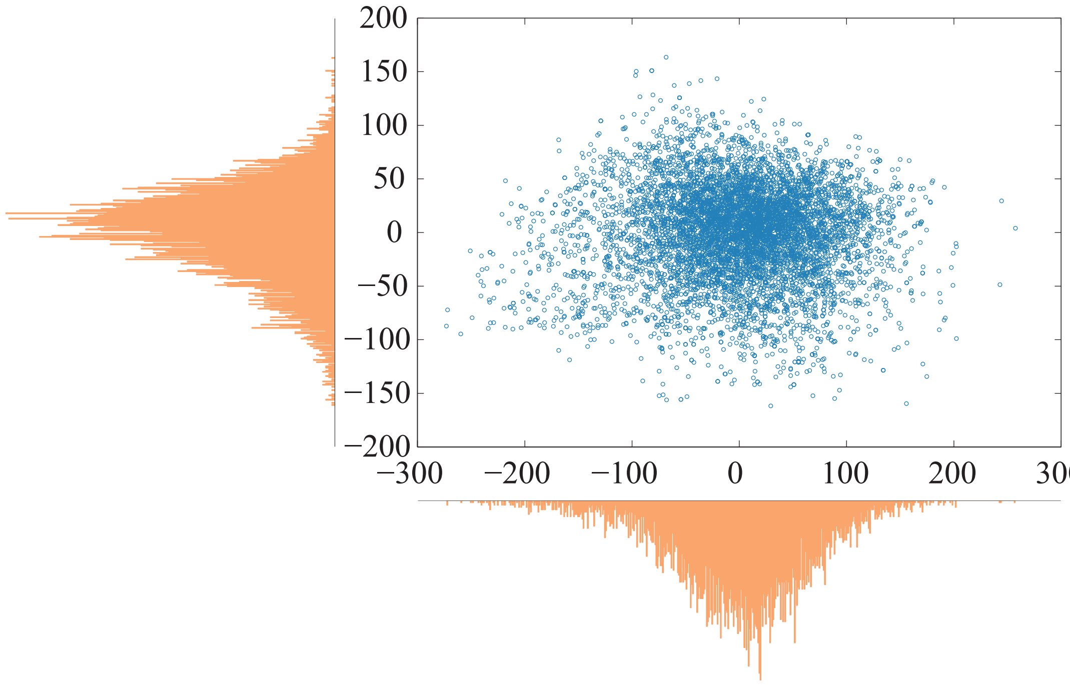


Fig. 5.2 Result of MDS for visualization of color scheme database

In Figure 5.2, the orange bars show a histogram of point distributions. The blue points denotes color schemes in the color scheme DB. The vertical and horizontal axes indicate eigenvectors extracted by the MDS.

The next process applies a k-means clustering technique to categorize the 2D map. Note that the number of neighboring clusters is set as $k = 9$ based on the dendrogram result. Figure 5.3 shows the results of k-means clustering. Each point is a color scheme in the DB. The coincident colored points have same cluster ID. Nine black points indicate the center of gravity of each cluster.

Final process assigns nine probability distributions on the basis of the Euclidean distances between each point and its center of gravity. Figure 5.4 shows the probability distribution of the brown cluster in Figure 5.3. The gradation colors show the probabilities. The reddish color denotes color schemes that have higher probabilities, and the bluish color denotes color schemes that have lower probabilities. A candidate is selected from the color scheme DB based on a probability distribution. Hence, nine candidates are stochastically chosen from the color scheme DB based on the probability distributions of each cluster as the initial population.

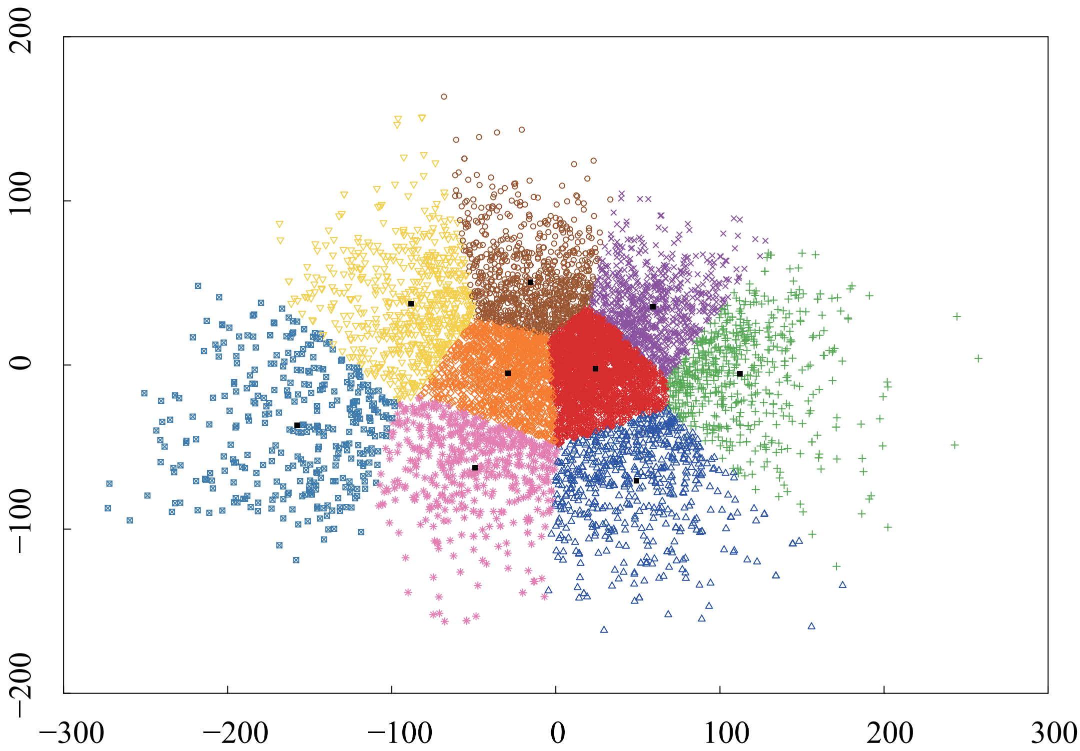


Fig. 5.3 Result of k-means clustering

STEP 2. Replace all genes

General IGAs are used to generate fonts or musical content by combining parameters (genes). In this study, the IGA does not generate color schemes; it displays color scheme candidates. This method replaces each gene of an individual color scheme with each statistic of the color schemes in the DB. First, the fitness value is calculated by comparing an individual with each DB color scheme. Then, all genes of the individual are replaced with the set of statistics that has the maximum fitness value among the dataset in the DB. The fitness value F is defined as follows:

$$F = 1.0 - \sum_i \omega_i A_i / \sum_i \omega_i, \quad (5.1)$$

$$A = \{\Delta L^*_{ave}, \Delta S_{ave}, \Delta h^*_{ave}, \Delta L^*_{C.V.}, \Delta S_{C.V.}, \Delta h^*_{SD}\}$$

Here ω is a weighting parameter, and A is a set of the difference values between the current selected color scheme and a DB color scheme with each statistic. In

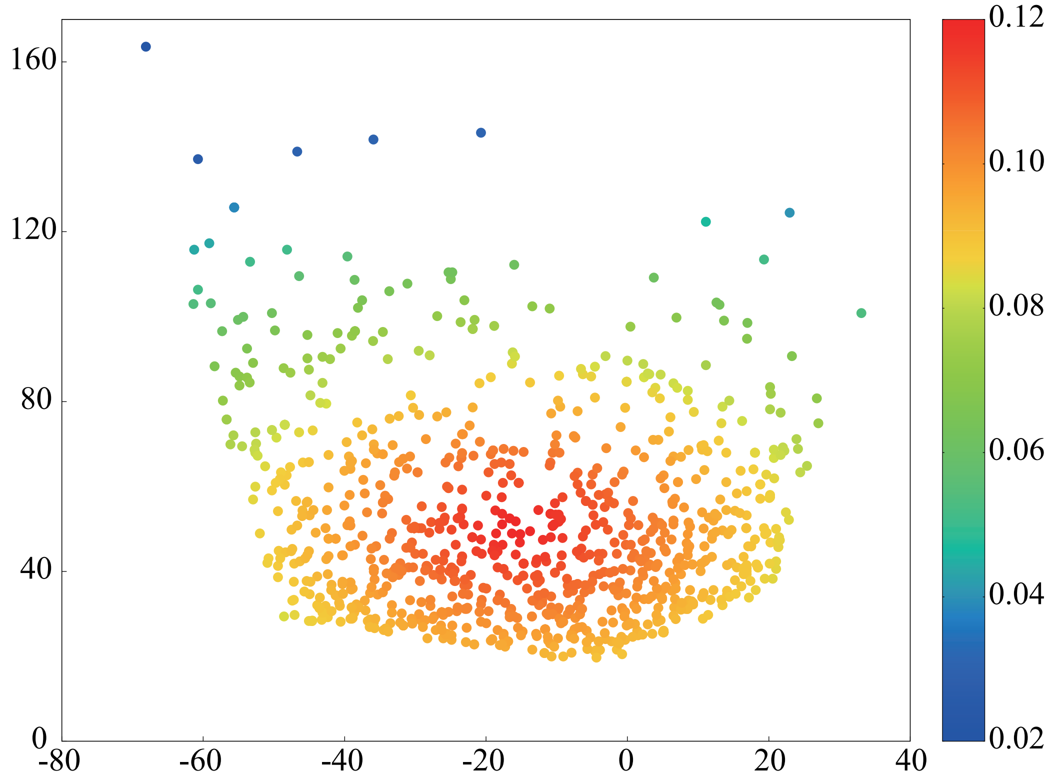


Fig. 5.4 Example of a probability distribution

this study, all weighting parameters are set to $\omega_i = 0.2 (i = 1, 2, \ldots, 6)$. In the future study, appropriate weighting parameters determined by user feedback will be investigated.

STEP 3. Display candidates

Nine candidate color schemes are displayed. These candidates are determined by each individual after the readout of the color schemes from the DB.

STEP 4. Evaluate candidates by user

A user evaluates the displayed candidates by choosing a candidate that is close to their desired color scheme. This method accelerates IGA search because the user performs an evaluation at each iteration [101]. If the user finds a desired color scheme, the process is terminated.

STEP 5. Select individuals

Here, the IGA uses Elite Selection and Roulette Selection as individual selection methods. In Elite Selection, the selected individual in STEP 4 (Elite A) and the individual with the maximum fitness (Elite B) become elites. In Roulette Selection, seven individuals are stochastically selected on the basis of Eq. (5.2).

$$P_i = \frac{s_i}{\sum_{i=1}^{N} s_i} \tag{5.2}$$

Here s_i is the fitness value between Elite A and each individual i. N is the number of all individuals excluding Elite A. This study sets $N = 8$. Note that Elite A remains a selected individual each time.

STEP 6. Crossover

The IGA has adopted the uniform crossover technique. This technique exchanges the corresponding statistics. In this IGA, four pairs of individuals are selected from all individuals including the two elites. This process considers color compatibility on the basis of hue and tone (brightness and saturation) [48, 49, 51, 56]. Thus, for brightness and saturation, an average value and a coefficient of variation are paired. Two pairs exchange the statistics with each value. For hue, the average value and the standard deviation are exchanged individually. Note that the probability of exchange is 50% for each statistic item. This process generates eight genes; however, one of them is deleted randomly. Final genes consist of two elites and seven generated genes.

STEP 7. Mutation

The mutation process also considers color compatibility. This process has three replacement target patterns: statistics in brightness and saturation, statistics in hue, and all statistics. Note that the replacement target pattern is determined by a one-third probability. This mutation process randomly chooses a color scheme from the DB. Each statistic value of an individual is replaced with each corresponding statistic of the chosen color scheme. Note that the probability of running this process is determined by the mutation ratio. Elite A is not run this process.

5.3 Color scheme search application

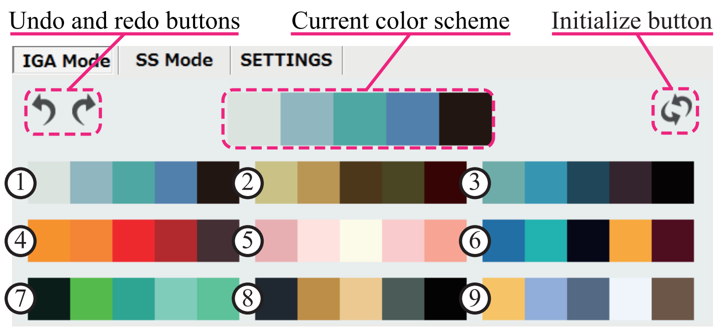
A color design support application has been implemented using the proposed method. Furthermore, this application incorporates four SS functions (Section 5.3.2). The combination of the proposed method and the four SS functions improves the search performance. This section describes the application and the details of the four SS functions. In addition, this application has a color transfer function. This section also illustrates the process flow. Figure 5.5 shows screenshots of each function in the implemented application.

5.3.1 IGA mode: the color scheme search function

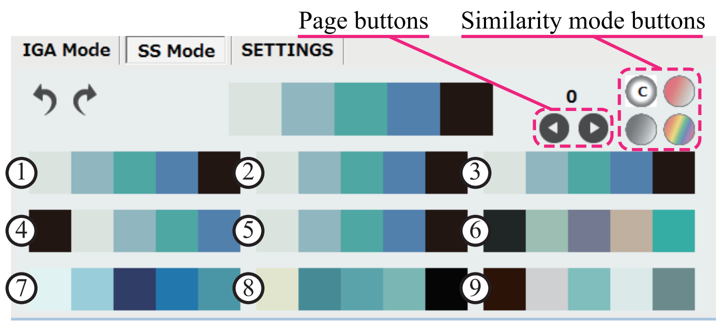
Figure 5.5(a) shows a screenshot of the color scheme search function, named IGA mode. The IGA mode applies the proposed statistics-based IGA. The statistics-based IGA enables searching of a color scheme based on an impression of overall color scheme. Thus, the various color scheme candidates can be displayed. Normally, users use this mode to search various types of color schemes as a global search. This system consists of undo and redo buttons, the display area for each color scheme, and an initialize button. This mode shows 10 color schemes simultaneously. The biggest color scheme shown in Figure 5.5(a) indicates the currently selected candidate. The other color schemes are the selectable candidates. This system displays various color scheme candidates based on user evaluation, and the displayed candidates are gradually narrowed with each iteration of the user selection operation. The evaluation is performed by clicking on a favorite color scheme. When the user chooses a candidate, the system presents other candidates.

5.3.2 SS mode: four similarity search functions

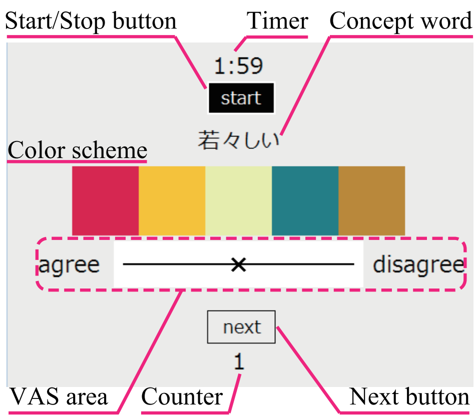
Figure 5.5(b) presents a screenshot of the SS mode. The SS mode has four different SS functions. One function is based on the color difference in $L^*a^*b^*$ color space. The other functions are based on hue, saturation, and brightness. Each SS function performs the following processes to calculate similarity values.



(a) IGA mode



(b) SS mode



(c) Experimental function

(d) Color transfer function

Fig. 5.5 Screenshot of the color design support application

Color difference: The SS function for color difference shows results based on the similarity S given by Eq. (5.3).

$$
\begin{aligned}
S &= minD, \\
D &= \{d_1, d_2, \dots, d_n\}, \\
d_i &= \sum_{j=1}^{\alpha} \left| diff(C_j^{sel}, C_{ij}) \right|, \\
C^{sel} &= \left\{c_1^{sel}, c_2^{sel}, \dots, c_\alpha^{sel}\right\}, \\
C &= \begin{pmatrix} c_{11} & c_{12} & \cdots & c_{1\alpha} \\ c_{21} & c_{22} & \cdots & c_{2\alpha} \\ \vdots & \vdots & \ddots & \vdots \\ c_{n1} & c_{n2} & \cdots & c_{n\alpha} \end{pmatrix}
\end{aligned}
\tag{5.3}
$$

where D is a set of the sum of values of color differences for every combination of a selected color scheme and each DB color scheme. d_i is the sum of color difference between a selected color scheme and the ith DB color scheme. Here, $diff$ is a formula to calculate the Euclidean distance between two colors in L*a*b* space using CIEDE2000 [117], which is a more sophisticated formula than normal Euclidean distance. C^{sel} and C are the set of color schemes in the selected color schemes and DB color schemes, respectively. c denotes a color value, n is the number of DB color schemes, and α is the number of colors in a color scheme. Note that this study set $n = 7850$ and $\alpha = 5$. All DB color schemes have a precomputed similarity S. This SS function shows results in ascending order.

Hue, saturation, and brightness: The other SS functions show results based on hue, saturation, and brightness variables. Some users may want to check color scheme candidates by changing hue, saturation, or brightness. In the case of a single color, it is easy to change each value continuously. However, in the case of five colors, preservation of the overall color impression is required. These SS functions use the statistics data discussed in Subsection 5.2.1. In these SS functions, the results consist of DB color schemes that meet the following conditions. The conditions are determined by the currently selected candidate depending on specific data (hue, saturation, or brightness). In variable space, a cylindrical volume is an acceptable volume in which the color schemes are chosen as the SS results, as is shown in Figure 5.6. In the case of brightness, L^*_{ave}

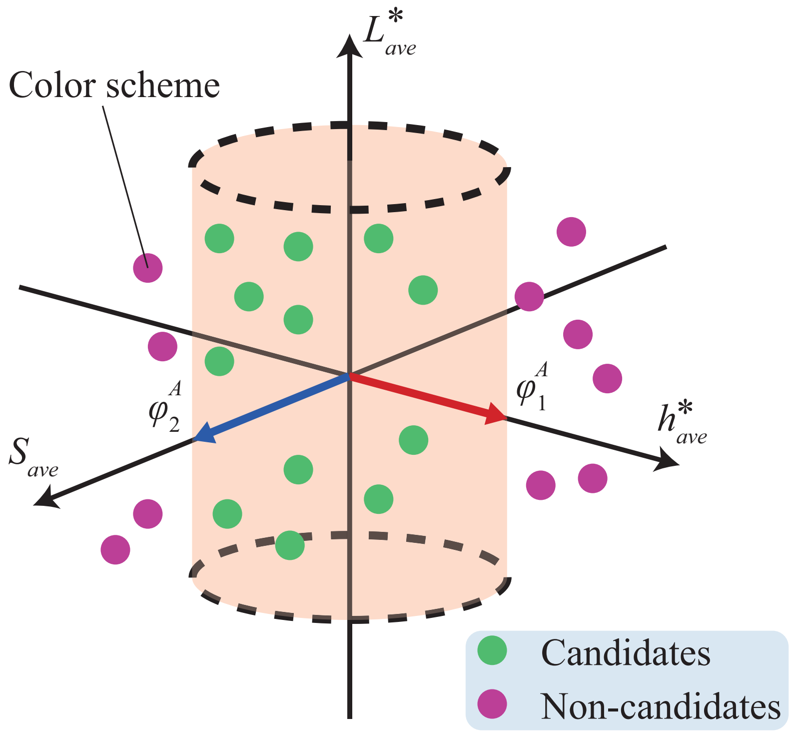


Fig. 5.6 Conceptual model for determining color scheme candidates in the case of brightness

and $L^*_{C.V.}$ are non-constrained variables. To construct the cylindrical volume, these SS functions set two constraint parameters φ^A and φ^B. φ^A is relative to the average values of hue, saturation, and brightness, φ^B is relative to the coefficient variations in saturation and brightness, and the standard deviation of hue. Figure 5.6 shows a conceptual model for determining the SS results in the case of L^*_{ave} (brightness). The orange cylindrical volume shows the acceptable volume for the $L^*_{ave}S_{ave}h^*_{ave}$ space. The origin is the currently selected color scheme. Each colored circle denotes DB color schemes in the space. The red and blue arrows indicate the constraint parameters φ_1^A and φ_2^A. Note that φ^A must set two different values when hue is a constrained variable. In Figure 5.6, the constraint parameters are the major and minor radii of the S_{ave}–h^*_{ave} plane. The color schemes denoted by green circles are chosen as the SS candidates, and the color schemes denoted by magenta circles are not selected. The SS results show all selected candidates on L^*_{ave} and $L^*_{C.V.}$. Thus, this process is also conducted for the coefficient of variation. SS results for hue and saturation are determined in the same manner. For example, in the case of brightness, the SS function candidates fulfill the following condition; $\frac{|\Delta h^*_{ave}|^2}{|\varphi^A_1|^2} + \frac{|\Delta S_{ave}|^2}{|\varphi^A_2|^2} \leq 1 \bigcap \frac{|\Delta h^*_{SD}|^2}{|\varphi^B|^2} + \frac{|\Delta S_{C.V.}|^2}{|\varphi^B|^2} \leq 1$. These parameters are set as $\varphi^A_1 = 18$, $\varphi^A_2 = 5$, $\varphi^B = 0.1$ respectively.

5.3.3 Color transfer function

This application has a color transfer function that changes the color pattern of a scalable vector graphics (SVG) image. SVG images do not deteriorate by color transfer processing and can be rendered most web browsers. The color scheme search function targets five colors. However, some SVG images are composed of more than five colors. Thus, a color reduction process is required for color transfer processing. The color reduction process continues to merge a pair of colors with the smallest color difference until the number of colors becomes five. This process is based on a process presented in [118]. Figure 5.5(d) shows a screenshot of this function. The color reduction process applies the specified SVG image. When the user chooses a color scheme using the color scheme search function, this color transfer function changes the color pattern of a SVG image based on the chosen color scheme. Each color assignment is determined by the color difference of CIEDE2000. The function computes the sum of color differences for all assignment patterns, and the assignment pattern with minimum value is applied.

5.4 Experimental evaluation of the color scheme search method

The proposed color search method can search a desired color scheme without the user having any knowledge or skills regarding colors. It is considered that setting a user's desired color scheme is difficult for novice users because the desired color scheme is often unclear in the user's mind. Furthermore, the user may change the desired color scheme frequently during the color scheme search. Therefore, it is impossible to evaluate whether the user can actually obtain a desired color scheme. Section 5.1 described some common impressions that people characteristically have of specific colors and color schemes. This study conducted an experiment that focused on this characteristic. In addition, this study also conducted an experiment using the color transfer function. The goal of the second experiment was to investigate the effectiveness of the practical use of the proposed method.

5.4.1 Details of the two experiments

The task of first experiment was to find a suitable color scheme for some concept words. Figure 5.5(c) shows the experimental function. This function has a start and stop button, a timer, a display area for a concept word, a display area for the selected color scheme, a visual analog scale (VAS) area (an evaluation area), a counter, and a next button. First, the participant searched for a suitable color scheme for the displayed concept word using the color scheme search system. If the participant found the best color scheme or exceeded the time limit, the experiment was terminated. The evaluation method adopted a VAS. A VAS is utilized for quantitative measurement of subjective phenomena [119]. Reips and Funke [120] have developed a VAS generator for a web survey. Takahashi and Hanari [121] have used a VAS to investigate color preference. Watanabe and Matsumoto [122] have also adopted a VAS to analyze student information skills. A VAS can adjust the maximum value of an evaluation. The participants may have different evaluation criteria; thus, a VAS responds to the evaluation of impressions derived from many options. The evaluation item of this experiment was "agree–disagree" scale, which has been used in many investigations after the Likert scale [123] was proposed. Thus, the participants were required to evaluate whether the color scheme gave the same impression as the concept word. The evaluation range of the VAS was from 0 to 250. When the participant selected a color scheme in the color scheme search function window, the experimental function window showed their selected color scheme. Then, the participant evaluated their impression using the VAS. Note that the cross mark of the VAS was not shown prior to the participant's evaluation.

The task of the second experiment was to determine the preferred color pattern for some SVG images. The participants could change the color pattern of each SVG image using the proposed color scheme search method. If the participant found the best color scheme or exceeded the time limit, the experiment was terminated. The participant evaluated the recolored SVG images using the VAS with a "like–dislike" scale. The SVG images were displayed sequentially, as is shown in Figure 5.5(d). The size of the display area was fixed at 500×500 pixels, and each SVG was scaled to fit in the entire display area.

In both experiments, the time limit was 2 min. Ten male graduate students in 20s participated in the experiment. The experimental equipment included the LCD monitors (FlexScan M1950-R, Size: 19 inch, Resolution: 1280×1024) and PCs (Intel Core i7 2.3GHz, 8GB RAM). In same cases, different equipment of equal performances was used. The color of the LCD monitor was adjusted using the following values; color temperature, 6500K; contrast, 50; brightness, 30. The distance between each participant and the LCD monitor ranged from 40 to 50 cm. All participants performed this experiment in the same room. The first experiment used 35 concept words described in [124]. The second experiment used 10 vector images selected from a website [*1]. See Appendix C.1 for all vector images. The DB was constructed by using 7850 color schemes from COLOURLovers.

5.4.2 Experimental results

All evaluation items and operation times were recorded for both experiments. Figure 5.7 and Figure 5.8 show the results of the first and second experiments, respectively.

In both results, the letters are the participants ID. The red dashed line indicates the average values of the experimental results. The black dashed line indicates the center value. Note that all evaluation values are normalized in the range [0, 100]. In the first experiment, 0 indicates "agree" and 100 indicates "disagree." The results are shown for each concept word. In the second experiment, 0 indicates "like" and 100 indicates "dislike." IDs, such as "I1," indicate each illustration (examples are shown in Figure 5.11 and Figure 5.12). The average time for the first experiment was 47.30 s. The average time for the second experiment was 51.97 s.

In the first experiment, all average values indicate "agree." The results for the concept word "Tranquil" strongly indicate an "agree" response. Figure 5.9 shows examples of the selected color schemes for "Tranquil." These examples have two features. Some color schemes consist of (1) similar tone (saturation and brightness) patterns and (2) similar hue patterns. The results indicate that the statistics-based approach works effectively.

This result indicates that the proposed method allowed users to obtain a

[*1] ALL-free-download.com, http://all-free-download.com/ (accessed in November 2013)

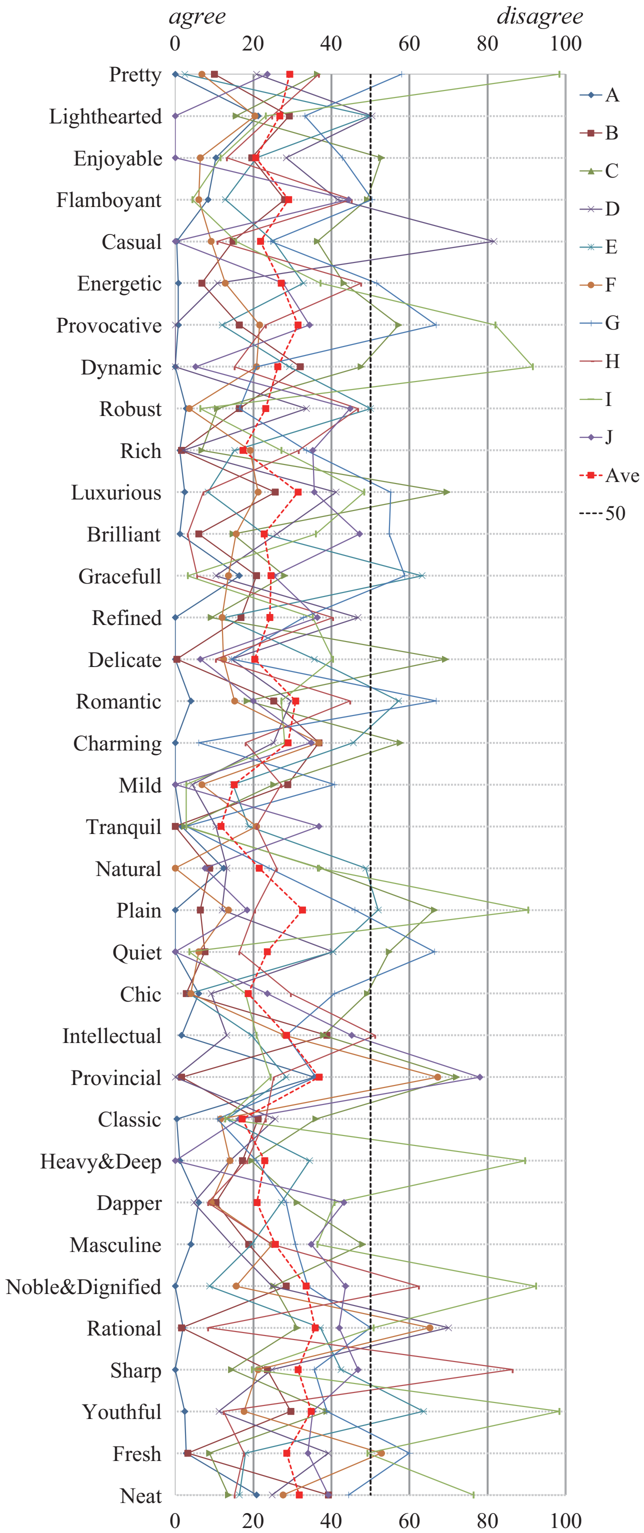


Fig. 5.7 Results of the first experiment (“agree–disagree” scale)

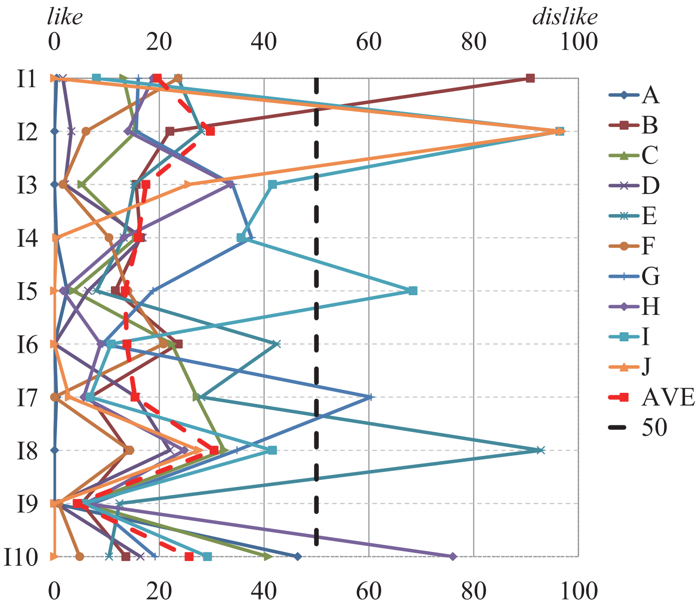


Fig. 5.8 Results of the first experiment (“like–dislike” scale)

Fig. 5.9 Examples of selected color schemes for “Tranquil”

desired color scheme based on concept words. Furthermore, the average operation time was 47.30 s. In the experiment discussed by Inoue et al. [69], which targeted three colors, the average operation time was approximately 1.5 min. However, the proposed method targeted five colors, and the operation time was less than that of the existing method proposed by Inoue et al.

In the second experiment, all average values indicate “like” responses. The results for “I9” strongly indicate “like” responses. Figure 5.10 shows examples of recolored images for “I9.” The common feature is that the silhouette regions (castle and bats) are darker colors. It is supposed that the castle and the bats in the image gave the specific meaning as “silhouette,” thereby, the partic-

Fig. 5.10 Examples of recolored images for "I9"

ipants fixed a darker color. From this assumption, the participants would focus on the other four colors in their color choice. Consequently, the participants could determine a favorite color pattern more easily and efficiently.

The operation time was only 3 s slower than the first experimental result. The participants could obtain a favorable colored illustrations using the color scheme search. Therefore, it is assumed that the proposed method has an acceptable level of practical usability. Figure 5.11 and Figure 5.12 show some examples of the recolored illustrations. Note that the ID numbers corresponding to Figure 5.8.

5.5 Conclusion of color scheme search method

This study aims to find a desired color scheme without requiring the user to have special skills or knowledge regarding colors. To achieve this goal, this study has proposed a color scheme search method using a statistics-based IEC method. The proposed statistics-based IEC method considers overall color scheme impressions. The proposed method provides the suggestions for various types of color scheme candidates and gradually narrows the candidates based on user evaluations. A color support application was implemented for experimental evaluations. This application introduced four SS functions and a color transfer function. To investigate the effectiveness of the proposed method, two experiments were conducted.

The experimental results confirm that the implemented application allows users to obtain a desired color scheme in less than 48 s. Relative to operation time, the proposed method is superior to the existing method proposed by

(a) Example A (ID: I1, I2)

(b) Example B (ID: I9, I10)

Fig. 5.11 Examples of recolored images

Inoue et al. [69]. In addition, the results of the second experiment indicate that the proposed method enables users to obtain some favorable recolored illustrations in less than 52 s. Therefore, it considered that the proposed color support method is valid for practical use. Future work will improve the proposed method by including the ability to respond to gradational color combinations and texture combinations.

(a) Example C (ID: I3, I4, I5)

(b) Example D (ID: I6, I7, I8)

Fig. 5.12 Examples of recolored illustrations

Chapter 6

Investigation of onomatopoeia for expressing kansei

Many types of media, such as comics, animations, posters, movies, and magazines, employ onomatopoeias as effective information media for everything from fashion to food. This study focuses on the ability of onomatopoeias to convey information effectively and easily. Especially in Japanese, there are a variety of onomatopoeias because they continue to be created as neologisms, which are commonly used in manga (Japanese comics) and advertising. The onomatopoeias are represented as a simple word, and most Japanese can understand their meaning from the phonological features. Some onomatopoeic neologisms are created when manga are translated into other language. In fact, the number of onomatopoeias has gradually increased all over the world. Use of onomatopoeias is a flexible and effective way to convey information. In particular, in Japanese, some onomatopoeias express emotions and feelings.

Before proceeding to detailed analysis, it is necessary to clarify the effectiveness of onomatopoeias for expressing kansei information. The focus of this study is twofold: (1) to investigate the effect of onomatopoeias that represent emotions because emotions are often an aspect of human communications and (2) to investigate the relationships between fonts and onomatopoeias by analyzing appropriate combination based on visual features. This study attempts to confirm the effect of onomatopoeias for emotion as kansei media. A photography system and an image retrieval system have been used to conduct an experimental investigation. The experimental results are expected to show the effectiveness of onomatopoeias as kansei media. Section 6.1 describes the systems and the experimental results. Essential relationships between fonts and onomatopoeias to determine appropriate combinations are also investigated. FFQs, which are the visual features of fonts, used to develop the analysis. The analysis and the results are presented in Section 6.2.

6.1 Utilization of onomatopoeias meaning human emotions

To investigate onomatopoeias, this study targets human emotions because they are strongly related to communication. Thus, this investigation targets onomatopoeias that represent emotions. There is a large vocabulary of onomatopoeias that convey emotion. Emotion is one of the elements of human memory. People can easily record their memories using a digital camera; however, a photograph cannot record emotions. Onomatopoeias can convey such information easily and effectively. Therefore, this study tries to embed emotions into an image using onomatopoeias. To conduct an experimental investigation, a photography system and an image retrieval system were implemented. These systems enable users to deal with emotions via onomatopoeias. The results of the experimental investigation confirm that it is possible to deal with emotions. In particular, it has been confirmed that the implemented image retrieval system enables users to search a target image based on emotions. Therefore, onomatopoeias can be effective utilized as kansei media. However it is difficult to use onomatopoeias when the onomatopoeias evoke similar emotions.

6.1.1 Introduction: onomatopoeias and emotions

Emotion is one of constituent elements of episodic memory. Emotion is closely related to thought process and unconscious cognition. For instance, people retain as the highly detailed long-term memories when they face emotionally intense circumstances. These are referred to as “flashbulb memories” [125]. The widespread use of digital cameras and smart phone has made digital images a convenient medium to record people’s daily lives. In addition, people can capture and store many photographs; however, it can be difficult to find a desired image in a photo collection. When someone searches for a desired image in their photo collections, their memories are closely related to the query data used for image retrieval. Thus, emotions are effective query data for image retrieval. In this study, photography and image retrieval systems that utilize onomatopoeias representing emotions have been implemented. The implemented photography system enables users to store an onomatopoeia tag when taking a photo. The implemented image retrieval system allows users to search for a target image using the onomatopoeia tags. An experimental investigation using these two systems may clarify the relationships between onomatopoeias and emotions and contribute to one of the primary goals of this study: to confirm the effectiveness of onomatopoeias as kansei media.

6.1.2 Application of onomatopoeias

Existing studies have reported the effectiveness of onomatopoeias. Fujino et al. [80] have reported that onomatopoeias are useful for sport coaching, when teaching complex body behaviors directly. Udo and Takano [81] have reported that onomatopoeias are effective in the education of disabled children. Onomatopoeias can help people understand complex information easily and intuitively by simplifying them. Hence, onomatopoeias are appropriate for conveying emotions with complex and unclear meanings. They can also be more effective than normal text information, such as “Anger” or “Happiness.” The Japanese onomatopoeias “Pun-Pun” means a condition of anger with crankiness, and “Muka-Muka” means a condition of anger associated with a person becoming rapidly filled with resentment. Japanese people can understand the subtle difference of these conditions easily.

For emotion input, a straightforward way is to select an onomatopoeic word directly from a list; however, this can become tedious. Ishibashi and Miyata [126] have reported that color information is useful for recognizing emotions. This study creates a list of onomatopoeias in which the onomatopoeias are categorized by four colors based on Plutchik’s wheel of emotions (Figure 6.1).

Plutchik’s wheel of emotions is categorized by eight different colors: yellow, orange, red, magenta, blue, cyan, green, and greenish yellow. In this wheel, the following pairs of colors have similar meanings: yellow and orange, red and magenta, blue and cyan, and green and greenish-yellow. The list of onomatopoeia in Figure 6.1 is presented in four colors (orange, red, blue, and green) because it is generally easier for people to recognize primary colors. Note that this list

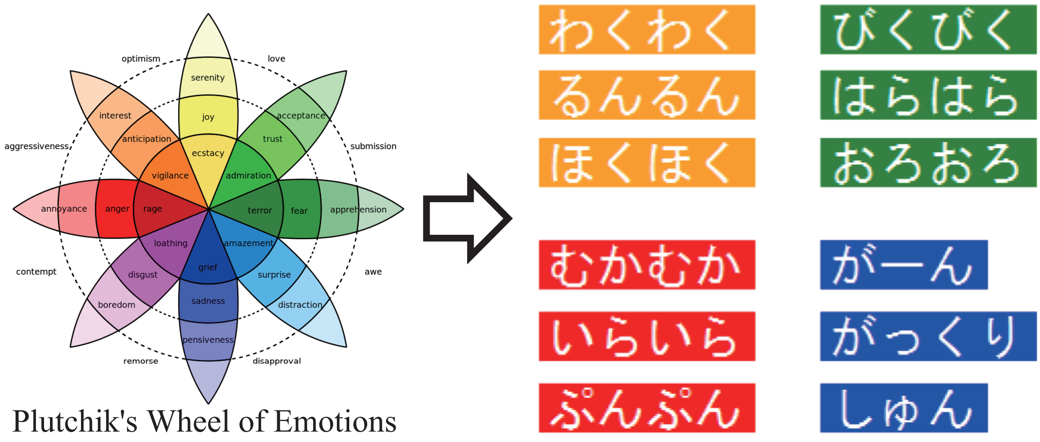


Fig. 6.1 Color-coded list based on Plutchik's wheel of emotions

uses orange rather than the primary color yellow because yellow is hard to see. The onomatopoeias list has 12 words based on categories of emotion [127]. The use of colors allows users to choose onomatopoeia easily and effectively.

6.1.3 Overview of two systems using onomatopoeias

This section gives a brief description of the photography and image retrieval systems using onomatopoeias. Figure 6.2 shows an overview of the systems.

In Figure 6.2, X is a user of the photography system, and Y is a user of the image retrieval system. When X takes a photo using a handheld device, such as a smart phone or a small tablet PC, he/she needs to infer the subject's emotion by selecting an onomatopoeia. Then, the photography system stores the photo with an associated onomatopoeia tag. In the image retrieval system, these photos and onomatopoeia tags are stored in a database. When Y chooses an onomatopoeia, this system returns the search results. In this case, Y must recall the subject's emotion in a target image. In addition, each photo is associated with corresponding tags in the search results, and these tags are displayed at the same time. It should be noted that X and Y could be the same person.

6.1.4 Details of two systems using onomatopoeias

This section describes the photography system and the image retrieval system in detail.

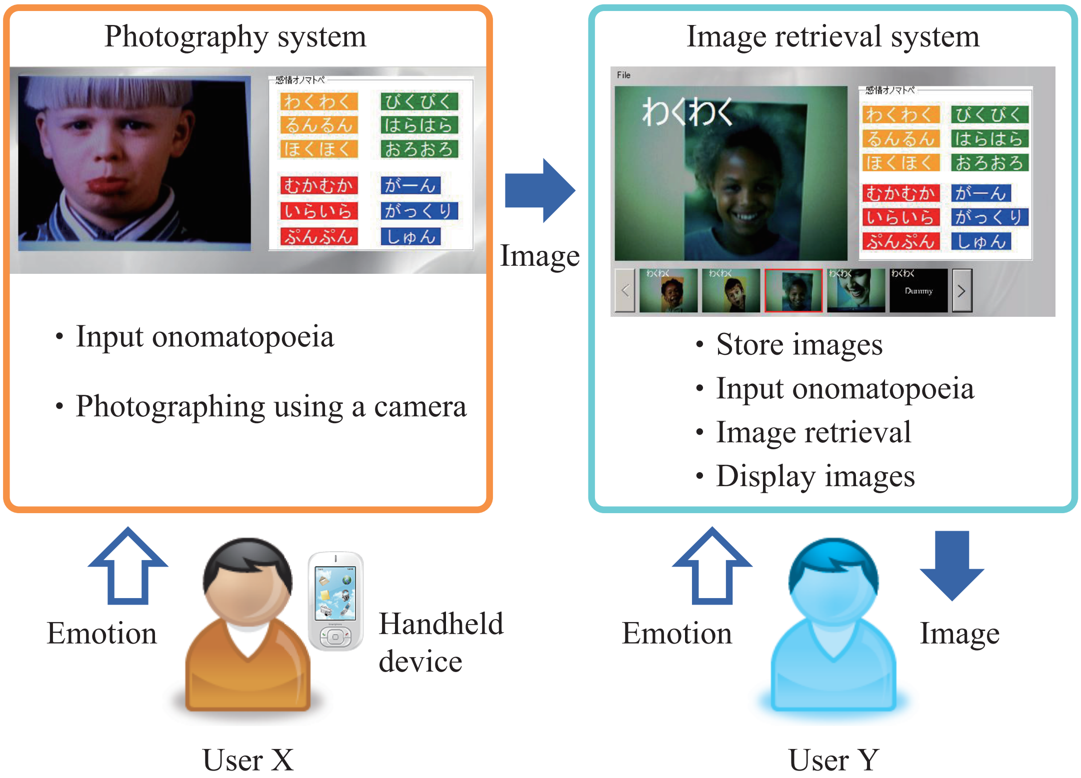


Fig. 6.2 Overview of the implemented systems

Photography system

For the photography system, automatic emotion detection is an ideal approach to obtain a subject's emotion. Several audio analysis methods [128, 129, 130] are also useful; however, high accuracy and flexibility are required for various users. Compared to these existing audio analysis methods, choosing the emotion by inferring a subject's emotion is a better method because it has high accuracy and can categorize each emotion. When a user chooses an emotion, the proposed system takes a photo automatically because the emotion selection button is synchronized with the shutter button. This system uses the input and storage method discussed in Section 6.1.2. Figure 6.3 shows a screenshot of the system.

In Figure 6.3, the left screen shows the captured image, and the right screen is the area for selecting an onomatopoeia. Note that the text of the onomatopoeia is not rendered on the captured image. This photography system stores an original photograph, text data of the onomatopoeia, and a coordinate value.

Fig. 6.3 Screenshot of the photography system

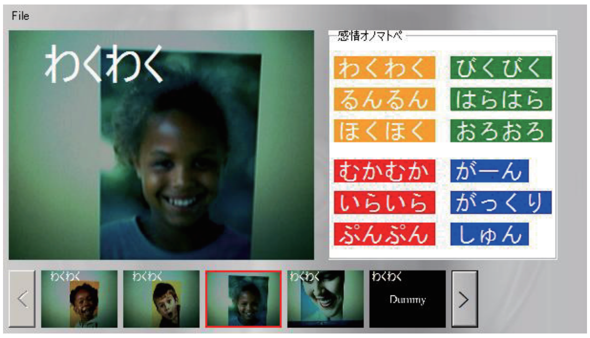


Fig. 6.4 Screenshot of the image retrieval system

This coordinate value is automatically determined by face recognition using OpenCV.

Image retrieval system

Existing image retrieval systems use image content information (colors and compositions) as query data [118, 131]. Such information is effective for image retrieval; however, these systems require manual creation of a database. When a user searches for their desired image from a photo collection, they must provide query data based on their memory. If a user cannot provide key words related to the image content, finding a desired image is difficult. Emotion information will assist image retrieval for such a situation. The photography system can record onomatopoeia tags and coordinate values, and the image retrieval system also uses these data. Therefore, this system allows users to retrieve an image using an onomatopoeic word as query data. In addition, the retrieval results show the text of the onomatopoeia; thus, users can find a desired image easily. Figure 6.4 shows a screenshot of the image retrieval system.

In Figure 6.4, the left screen displays the retrieval results, and the right screen

Fig. 6.5 Flow of the experiments

is the area for selecting the onomatopoeia. First, a user recalls a target image. Next, he/she chooses the appropriate onomatopoeia. Then, the search results are displayed in the bottom thumbnail window. The largest image in the left screen is the user selected image, and the other search results are shown as thumbnails. This system enables users to search for an image using emotion information.

6.1.5 Overview of evaluation experiments

This study conducted two experiments to evaluate the two implemented systems. Experiment 1 investigated the usability of the implemented photography system. Experiment 2 investigated the effectiveness of the image retrieval system. This section presents brief descriptions of each experiment.

Experiment 1

Input and storage of tags denoting emotion must be easy for the photography system to be effective. This experiment investigated the ease of input and storage of tags. This experiment targeted portrait images, in which a user can see the subjects' facial expressions. In this experiment, the participant viewed an image on the display and then selected an onomatopoeia based on their understanding of the subject's emotion, as is shown in Figure 6.5.

This experiment used 20 portraits for all participants. The portraits were selected from Microsoft® clip art. All captured photos in this experiment were used in Experiment 2.

Experiment 2

Experiment 2 investigated the search performance of the implemented image retrieval system. The evaluation item was a success rate, which indicates whether the target image is shown in the search results. The 20 captured images in Experiment 1 were used as the displayed images. This experiment assumed two conditions; the target image is clear or unclear. If the image was unclear, a person may not be able to identify the facial expressions. To obscure each facial expression, image blurring was applied to 10 randomly selected images. This experiment used clear 10 images and 10 blurred images. These images were displayed one at a time using *Windows Photo Viewer*, and each displayed image became a target image. This experiment used two systems: (1) a display system for each target image and (2) an image retrieval system. First, the participants check the target image on the display system. Next, they infer the subject's emotion in the displayed image. Then, they select an onomatopoeia using the image retrieval system. The image retrieval system then returns all images with the specified onomatopoeia tag. If the search results include a target image, this system judges the experiment as a "success." This experiment had two discriminant rules: "Normal" and "Categorical." "Success" is achieved if a target image is included in the search results ("Normal"). "Success" is also achieved if a target image is in the same emotional category of onomatopoeias ("Categorical"). In Figure 6.1, equal background colors indicate the same emotional category. If a participant selects "Waku-Waku" for a target image that has an "Uki-Uki" tag, it is judged as a categorical success, because those onomatopoeias belong to the same category. Note that all participants conducted Experiment 2 one week after Experiment 1.

6.1.6 Experimental evaluation results

In this study, five Japanese graduate students participated in the experiments. All participants were sufficiently proficient in Japanese to utilize onomatopoeias. The results of Experiment 1 show that four participants answered, "This input method can be used in the same way as general digital cameras," and one participant answered "This input method is easier than general digital cameras." This confirms that using onomatopoeias is easy to store tags denoting emotion.

One week after Experiment 1, the same five participants viewed 20 images taken by each participant. Table 6.1 shows the success rates for "Normal," and Table 6.2 shows the success rates for "Categorical." The letters (A, B, C, D, and E) identify the participants.

The results shown in Table 6.1 indicate that the results for the clear images

Table 6.1 Results for Experiment 1: Normal

Image type	A	B	C	D	E	Average
Normal image	40%	40%	20%	20%	80%	40%
Blurred image	10%	0%	20%	20%	10%	12%

Table 6.2 Results for Experiment 2: Categorical

Image type	A	B	C	D	E	Average
Normal image	90%	80%	70%	50%	90%	76%
Blurred image	50%	50%	40%	50%	50%	48%

are better than those for the blurred images. However, the results are lower values. Even if a participant looked at normal images, it was difficult to select the correct onomatopoeia tags. Thus, it is considered that the participants did not use onomatopoeias for emotions properly. The average success rate for the blurred images was 12%; thus, the participants did not fully remember the emotions.

Table 6.2 shows that the results for the clear images are better than the results for the blurred images. These results are higher than the results shown in Table 6.1. Average success rate for the blurred images was 48%. Thus, it is evident that the participants were able to remember the emotions for each category. The results indicate that onomatopoeia is suitable for image retrieval as second or third query data. In future, it will be necessary to validate the effectiveness of using onomatopoeias as a method to record emotion experienced in the course of normal day using handheld devices.

6.1.7 Conclusion: onomatopoeias and emotions

This study has implemented a photography system and an image retrieval system using onomatopoeias that represent human emotions. The photography system enables users to input and store tags denoting emotion easily when they take a photo. The image retrieval system allows users to search for a desired image from their photo collections using onomatopoeia tags.

To verify the effectiveness of these systems, two evaluation experiments were conducted. The results of the evaluation of the photography system indicated that the system allows users to enter emotion information easily, and the results for the categorical discriminant rule showed higher values than the results for the normal discriminant rule. Therefore, it is considered that the emotions were retained in user memory for each emotion category. Consequently, some onomatopoeias enable users to input tags denoting emotion easily, and this method supports image retrieval through the use of emotion data as second or third query data. The results indicated that, through the use of onomatopoeias categorized by emotion, it is possible to utilize onomatopoeia as kansei media to deal with emotions.

In future, further examination and discussion of the effectiveness of onomatopoeias via practical experiments using handheld devices is required.

6.2 Analysis of suitable fonts for onomatopoeias

Onomatopoeias are usually used effectively and intuitively in daily conversation. Various types of onomatopoeias are used in Japanese animations and comics, and particular fonts are used to emphasize onomatopoeic meaning. This study focuses on the relationship between onomatopoeias and fonts to find appropriate combinations. In Chapter 3, FFQs, which are the visual features, are presented. This study analyzes a suitable font for onomatopoeias using the FFQs. From the analysis results, it is affirmed that four tendencies are related to the phonemes in onomatopoeias and the meaning of onomatopoeias. This section describes an experiment conducted to analyze the relationships between fonts and onomatopoeias.

6.2.1 Introduction: onomatopoeias and fonts

An onomatopoeia has high communicability because the information it conveys can be understood intuitively. Japanese onomatopoeias are often utilized in many different contexts, from daily conversation to education of disabled children [81] and sport coaching [80]. The fonts used for onomatopoeia enhance the meaning and contribute to easy and effective communication. Japanese animations and comics use onomatopoeias combined with special effects, such as sparkle effect and textured text effect, to express characters' feelings or the atmosphere of a scene. Hence, appropriate combinations of onomatopoeias and fonts to facilitate communication in many information media have been inves-

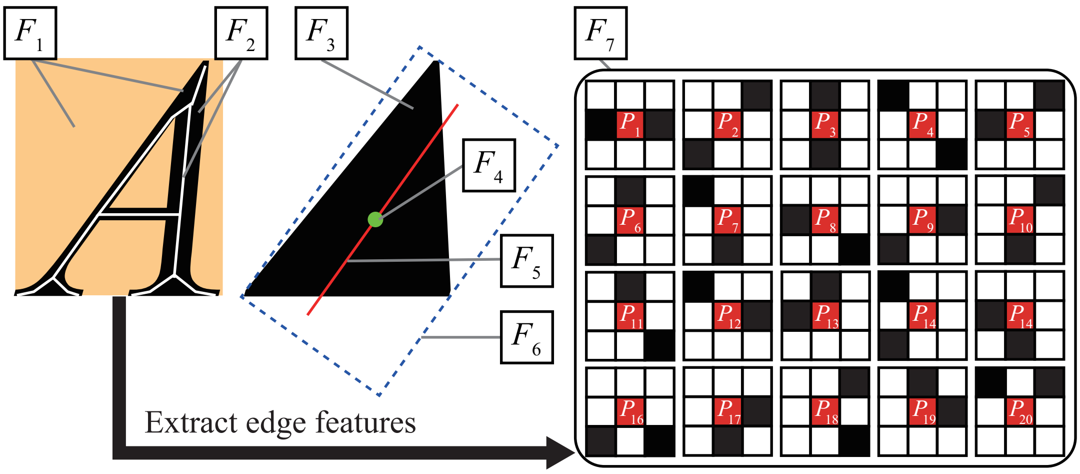


Fig. 6.6 Font feature quantity

tigated. However, the existing studies [132, 133] have focused on the legibility of fonts. Li et al. [134] focused on the visual expression of typefaces and design characteristics. However, they have not considered the meaning of each word. Thus, the relationship between fonts and onomatopoeic words is unclear. This study attempts to determine suitable fonts by focusing on the relationship between fonts and onomatopoeias to find appropriate combinations.

6.2.2 Analysis approach

This section describes a method for choosing and an analytical approach using FFQs. The FFQs are composed of seven features quantities. Figure 6.6 provides a simple illustration of FFQs.

In Figure 6.6, F_1 denotes contrast, F_2 is line width, F_3 is circularity (complexity), F_4 is center of gravity coordinate, F_5 is angle, F_6 is aspect ratio, and F_7 is edge pattern. This analysis looks at the FFQs of each font to investigate the relationship between fonts and onomatopoeias. FFQs are described in detail in Chapter 3.

Target fonts and onomatopoeias in the analysis

The analysis used 360 fonts. Some fonts used were freely available on the Internet; other came from a commercial font package (FONT×FAN HYBRID, Font Alliance Network). Both hiragana and katakana characters were used. Thirty-six onomatopoeias were divided into three categories: emotion, tactile sensation, and other (sound, temperature, and velocity). There were 12 onomatopoeic words in each category. The onomatopoeias were selected from three references [86, 127, 135]. There were no duplication of meaning. All target onomatopoeias are listed below by category.

Emotions [135]
: ぎんぎん (Gin-Gin), うきうき (Uki-Uki), ぬくぬく (Nuku-Nuku), ゆたゆた (Yuta-Yuta), よれよれ (Yore-Yore), しょぼしょぼ (Syobo-Syobo), びくびく (Biku-Biku), いらいら (Ira-Ira), むかむか (Muka-Muka), るんるん (Run-Run), おろおろ (Oro-Oro), のたのた (Nota-Nota)

Tactile sensations [86]
: もちもち (Mochi-Mochi), とろとろ (Toro-Toro), ぷるぷる (Puru-Puru), すべすべ (Sube-Sube), ぷちぷち (Puchi-Puchi), けばけば (Keba-Keba), べとべと (Beto-Beto), ぬめぬめ (Nume-Nume), くにょくにょ (Kunyo-Kunyo), かさかさ (Kasa-Kasa), ちくちく (Chiku-Chiku), じょりじょり (Jyori-Jyori)

Other [127]
: がやがや (Gaya-Gaya), ひそひそ (Hiso-Hiso), ざわざわ (Zawa-Zawa), しーん (Shīnn), どしどし (Doshi-Doshi), とことこ (Toko-Toko), ほかほか (Hoka-Hoka), ひやひや (Hiya-Hiya), すいすい (Sui-Sui), のろのろ (Noro-Noro), やわやわ (Yawa-Yawa), かちかち (Kachi-Kachi)

Font choice method

This experiment uses a lot of onomatopoeias and fonts. It would require a considerable effort to select suitable fonts for all onomatopoeias manually. The font search application, which is detailed in Chapter 3, is proposed to reduce the amount of effort. A screenshot of the application is shown in Figure 6.7.

This application displays nine font candidates. The subject chooses a suitable font among the candidates for the target onomatopoeia. By repeating this procedure, the subject can find the best font easily and efficiently. In the experimental results presented in Chapter 3, it was evident that the application enables a user to find a desired font in eight steps. Therefore, this experiment also set the maximum number of operations to eight. However, a subject may not be able to obtain their desired font within eight steps; consequently, an additional experiment was conducted. In this additional experiment, all fonts chosen by each subject in the first experiment, are presented simultaneously

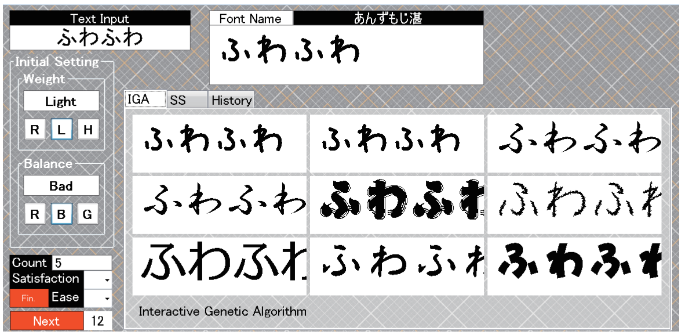


Fig. 6.7 Screenshot of the font search application

and the subject selects a suitable one. This study analyzes the data using weighting parameters that are given by this additional experiment. The analysis data is the weighted average of FFQs using the weighting parameters. The additional experiment contributes to the appropriate selection of fonts. Six graduate students participated in the first experiment; 10 graduate students participated in the additional experiment. The six subjects who participated in the first experiment also participated in the additional experiment.

Analysis approach using FFQs

FFQ depends on letters or fonts. This analysis adopts Z-score given by $Z = 10(F_i - F_i^{Ave})/F_i^{std}$. Here, F_i is ith FFQ, F_i^{Ave} indicates the weighted average value based on the experimental results, and F_i^{std} is the standard deviate of all fonts. This analysis calculates Z-scores for all subjects' chosen fonts. If the absolute value of a Z-score is high, it is supposed that the FFQ is the characteristic factor related to font selection. To reveal the common features, this analysis uses two analytical approaches.

The first focuses on the meaning of onomatopoeias. The second is a phonology-based approach focusing on the phonemes in onomatopoeias. One of the most common frameworks in psychology includes two main dimensions of emotions: arousal (high or low) and valence (positive or negative) [136]. This study assigns dimensions to 12 onomatopoeias on the arousal–valence map shown in Figure 6.8 to quantify each onomatopoeia.

Hayakawa et al. [86] have reported three main dimensions for tactile sensations: roughness, hardness, and moistness. Note that this analysis uses the measurement values from the distribution map provided by Hayakawa et

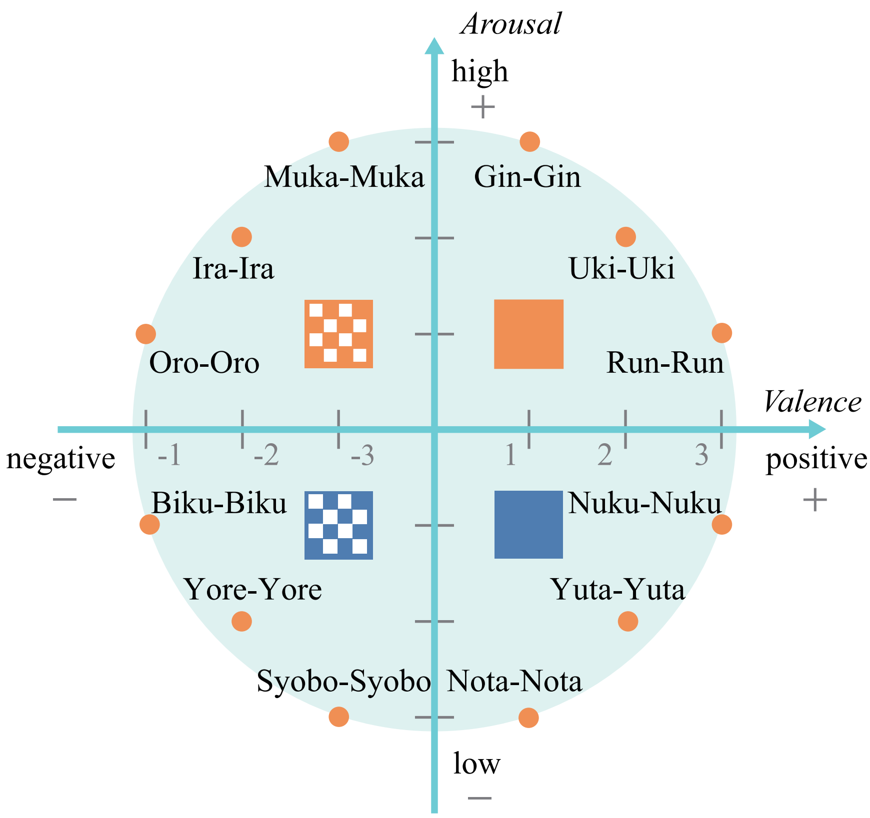


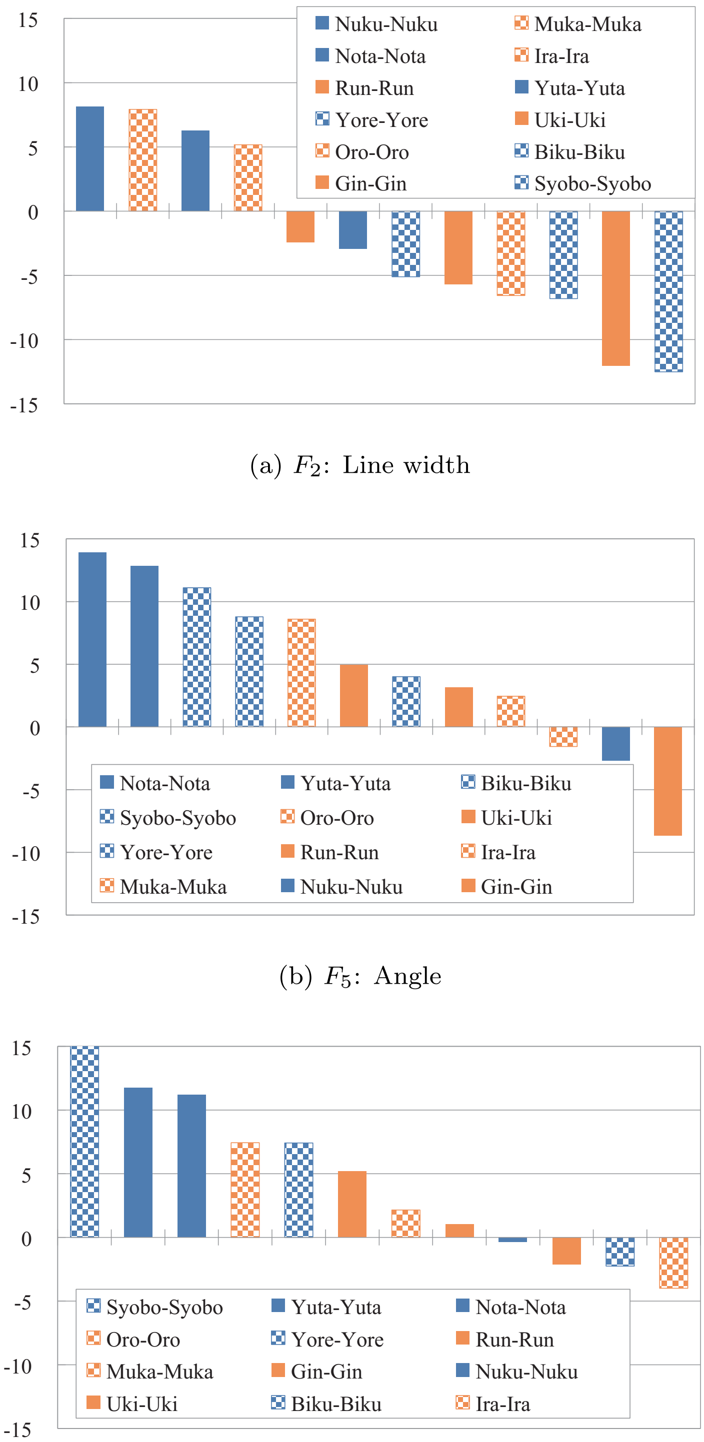
Fig. 6.8 Distribution of onomatopoeias in Arousal–Valence space

al. [86]. For the "other" category, pairs of antonyms were compared because all onomatopoeias in this category have an antonym. In addition, the effect of phonemes is analyzed based on the vowel and consonant in first mora of the onomatopoeias.

6.2.3 Results and discussion

The analysis results showed obvious characteristic tendencies for hiragana; however, katakana did not show such obvious characteristic tendencies. Hence, this section presents for hiragana. Figures 6.9 and 6.10 show the characteristic results for emotions and tactile sensations, respectively. Figure 6.9 shows the results of the phonological analysis based on the vowel and consonant in first mora of onomatopoeias.

Note that in Figures 6.9–6.14, the y-axes show Z-scores. The results presented in Figures 6.9 and 6.10 are sorted in descending order of Z-scores. In Figures

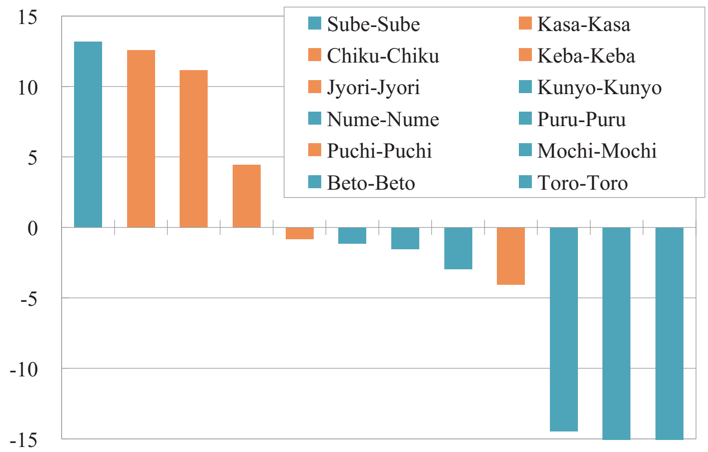


(a) F_2: Line width

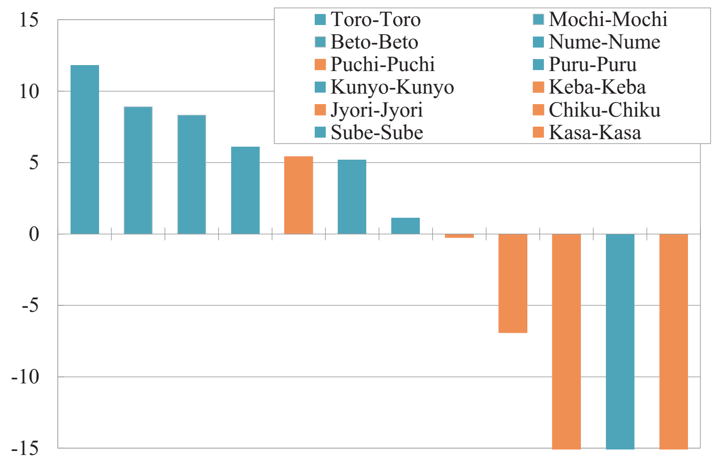
(b) F_5: Angle

(c) F_6: Aspect ratio

Fig. 6.9 Analysis results for emotions



(a) F_1: Contrast



(b) F_2: Line width

Fig. 6.10 Analysis results for tactile sensations

6.11 and 6.13, the x-axes show each FFQ. In Figures 6.12 and 6.14, the x-axes show the edge patterns of F_7 (P_i denotes ith pattern of F_7). The range of Z-scores in each figure is $[-15, 15]$ because it is assumed that a score grater than 15 indicates a sufficiently characteristic tendency.

Tendency 1: In Figure 6.9, the colors or patterns of each bar correspond to each quadrant in Figure 6.8. Figure 6.9(a) shows Z-scores of F_2 (line width); the scores for the onomatopoeias in the second and fourth quadrants were high. In the other words, the onomatopoeias that convey "positive and pleasant"

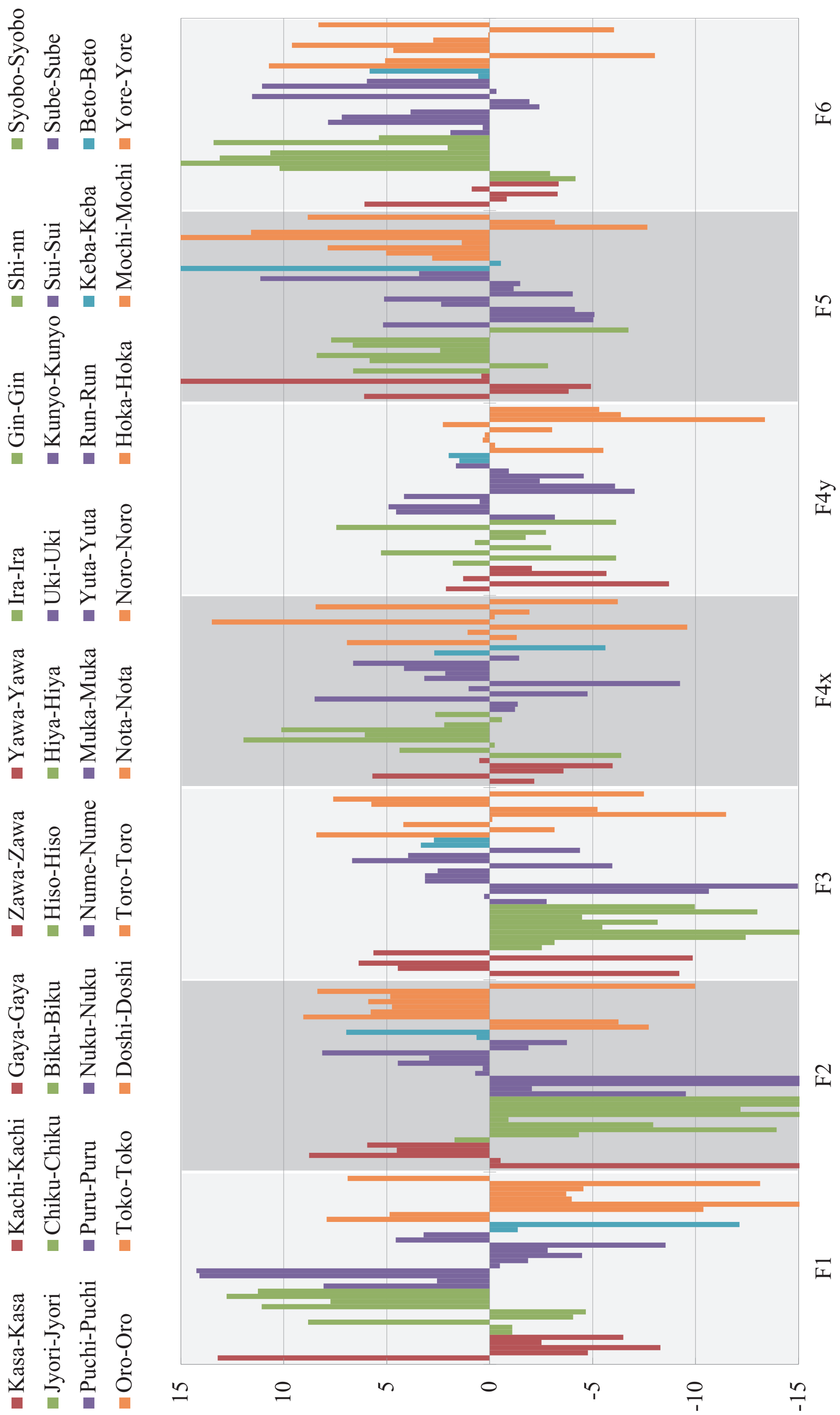


Fig. 6.11 Results of the phonological analysis: Vowel

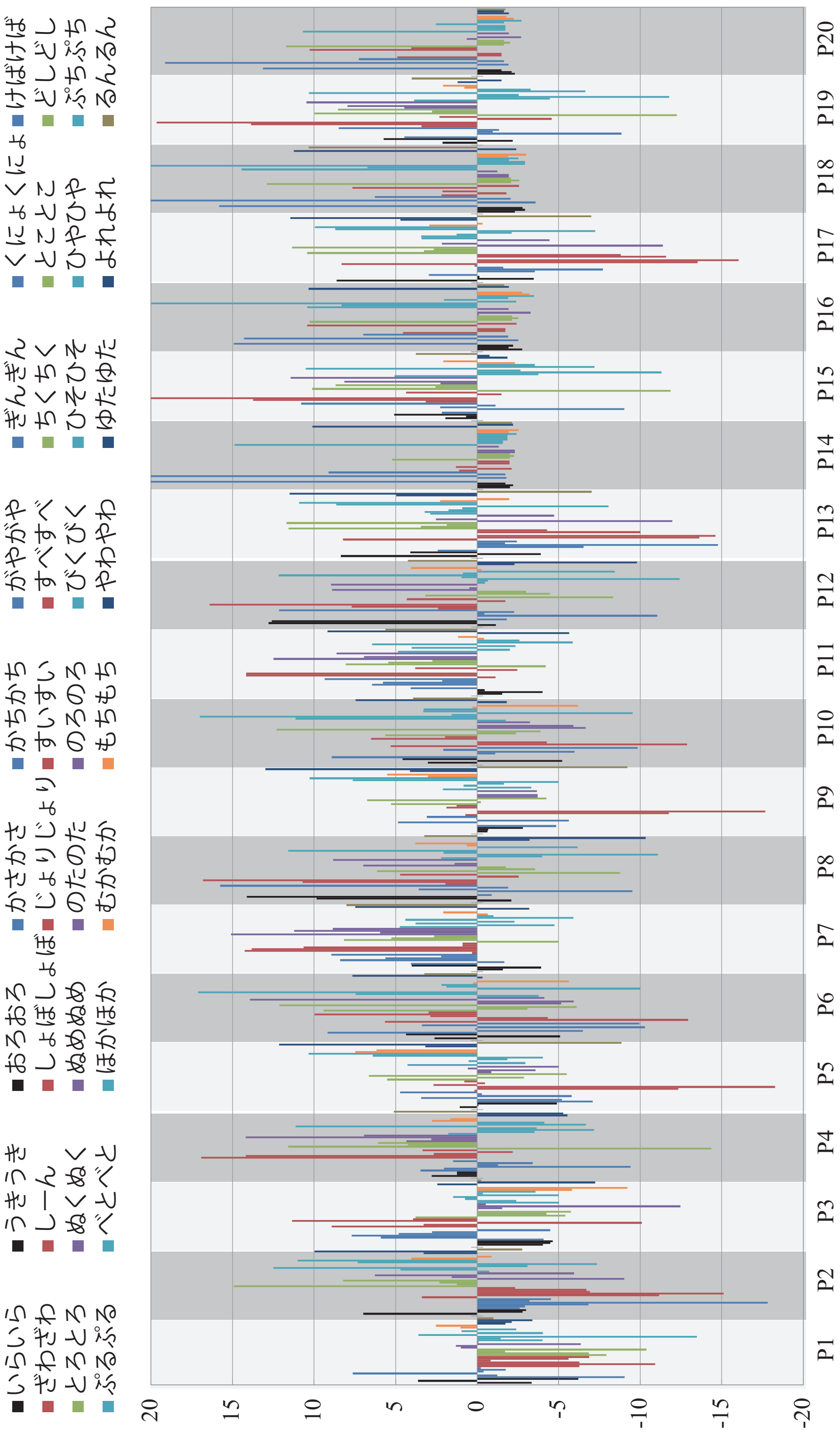


Fig. 6.12 Results of the phonological analysis: Vowel, F_7

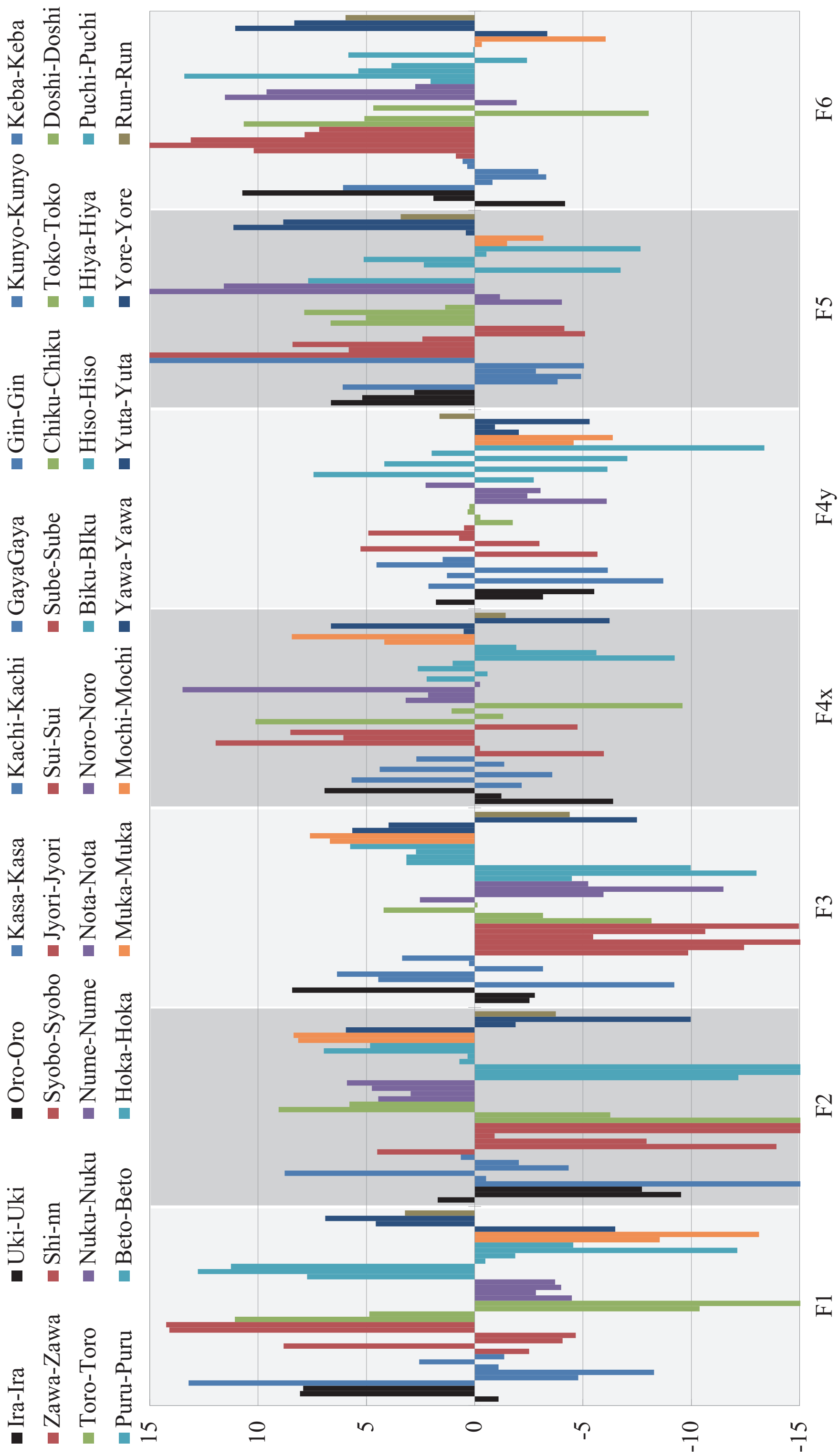


Fig. 6.13 Results of the phonological analysis: Consonant

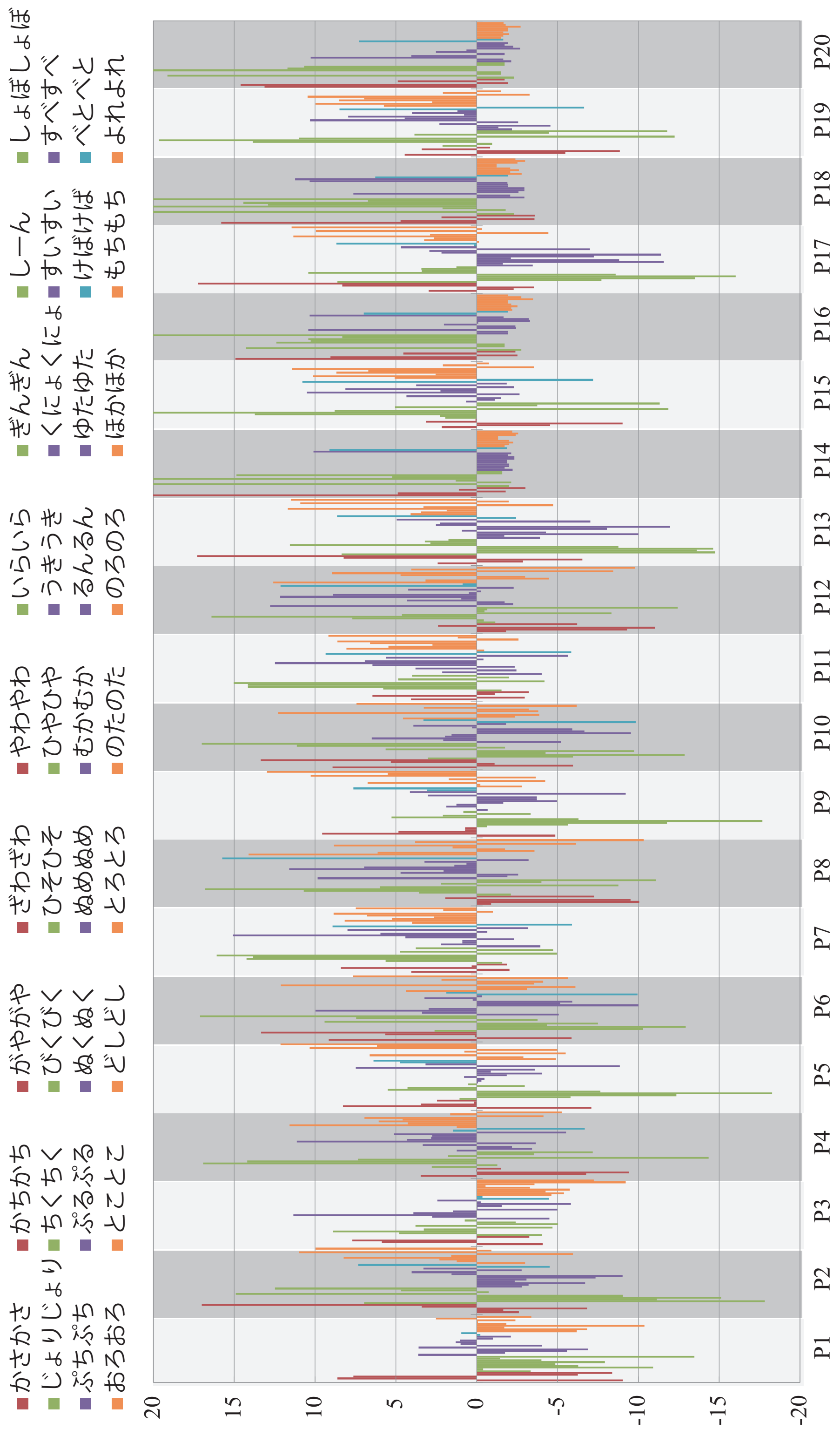


Fig. 6.14 Results of the phonological analysis: Consonant, F_7

Table 6.3 Results of the test for no correlation in emotions

Font feature quantity	Correlation coefficient r	t value	p value
F_5: angle	-0.680	2.931	0.015
F_6: aspect ratio	-0.676	2.898	0.016

Table 6.4 Results of the test for no correlation in tactile sensations (hardness)

Font feature quantity	Correlation coefficient r	t value	p value
F_1: contrast	-0.640	2.635	0.025
F_2: line width	0.666	2.824	0.018
P_{14}: smoothness(F_7)	-0.738	3.457	0.006
P_{16}:	-0.788	4.043	0.002
P_{18}:	-0.780	3.943	0.003
P_{20}:	-0.767	3.785	0.004

or "negative and unpleasant" meanings are related to thin fonts. In contrast, the onomatopoeias that convey "positive and unpleasant" or "negative and pleasant" meanings are related to bold fonts. Figures 6.9(b) and 6.9(c) show Z-scores of F_5 (angle) and F_6 (aspect ratio), respectively. In both figures, the blue bars (negative) are higher values. The results of the test for no correlation revealed all correlations between the arousal-axis and the angle or the aspect ratio, as shown in Table 6.3. In Table 6.3, the correlation coefficient r shows negative values and a p value less than 0.05 (level of significance 5%). These results indicate that there is a strong negative correlation between the arousal-axis and the angle or the aspect ratio.

Tendency 2: In Figure 6.10, cyan denotes onomatopoeias meaning soft and orange denotes onomatopoeias meaning hard. The cyan bars indicate low contrast and thin fonts; the orange bars indicate high contrast and bold fonts. Tables 6.4–6.6 show the correlation coefficient r, t values and p values. Note that the significance level for all p values in Tables 6.4–6.6 is less than 5%. The results of the test for no correlation revealed all correlations between the hardness-axis and the contrast or the line width, as shown in Table 6.4. In addition, the test results show all correlations between Pattern F_7 (P_{14}, P_{16}, P_{18} or P_{20} in F_7) and each axis of tactile sensations (roughness, hardness, and moistness), shown in Tables 6.4–6.6. Pattern F_7 indicates higher values in the case of fonts with

Table 6.5 Results of the test for no correlation in tactile sensations (roughness)

Font feature quantity	Correlation coefficient r	t value	p value
P_{14}: smoothness(F_7)	-0.640	2.633	0.025
P_{16}:	-0.635	2.603	0.026
P_{18}:	-0.727	3.349	0.007
P_{20}:	-0.649	2.696	0.022

Table 6.6 Results of the test for no correlation in tactile sensations (moistness)

Font feature quantity	Correlation coefficient r	t value	p value
P_{14}: smoothness(F_7)	-0.727	3.351	0.007
P_{16}:	-0.736	3.442	0.006
P_{18}:	-0.829	4.679	0.001
P_{20}:	-0.777	3.898	0.003

rough edges. Through this analysis, it is confirmed that the onomatopoeias that mean dry, hard, and rough, such as Keba-Keba and Jyori-Jyori, are related to the rough edged fonts.

Tendency 3: All onomatopoeias in the other category have antonym. To analyze these onomatopoeias, the results of each FFQ were divided into two groups: the lower value group and the higher value group. If the Z-score of an onomatopoeia is higher than that of the antonym onomatopoeia in F_1, the onomatopoeia belongs in the higher value group. The results of the student's t-test for the higher value group and the lower value group are shown in Table 6.7. Note that all underlined values in Table 6.7 have a significance level less than 5%. The results shown in Table 6.7 indicate significant differences in most font feature quantities. Hence, it is supposed that the meaning of onomatopoeia affects the font choice.

Tendency 4: Bar charts sorted in ascending order of the vowel or consonant in the first mora of the onomatopoeias are presented in Figures 6.11 and 6.13, respectively. In Figures 6.11 and 6.13, the uniform colored bars indicate the same vowel or the same consonant. In these results, the onomatopoeias categorized by the same vowel or the same consonant show similar Z-scores. In particular, the results for F_2, F_3, and F_6 indicate similar tendencies. Therefore, it is supposed that the phoneme of onomatopoeias affect line width, circularity,

Table 6.7 Results of t-test for other (all values $\times 10^{-3}$)

FFQ	F_1	F_2	F_3	F_{4x}	F_{4y}	F_5
p value	3.27	1.41	10.0	0.82	32.7	3.04
F_6	P_1	P_2	P_3	P_4	P_5	P_6
30.9	6.47	55.7	88.2	6.86	72.4	1.34
P_7	P_8	P_9	P_{10}	P_1	P_{12}	P_{13}
3.66	5.24	118.0	5.27	21.9	3.57	18.8
P_{14}	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}	P_{20}
135.3	1.49	80.1	23.1	87.2	3.65	82.5

and aspect ratio.

The four tendencies can be summarized as follows.

Tendency 1

In the onomatopoeias of emotions, F_5 (angle) and F_6 (aspect ratio) correlate with the arousal-axis on the map of tactile sensations [86]. Italic or slim-line style fonts tend to be chosen for the onomatopoeias in the third and fourth quadrants of Figure 6.8. The results of F_2 (line width) show that thin fonts are chosen for onomatopoeias in the first and third quadrants of Figure 6.8. In contrast, bold fonts are selected for the onomatopoeias in the second and fourth quadrants.

Tendency 2

In the onomatopoeias for tactile sensations, F_1 and F_2 (darkness) correlate with the hardness-axis on the tactile sensations map [86]. Thin fonts are chosen for the onomatopoeias meaning hard, and bold fonts are chosen for the onomatopoeias meaning soft. Pattern F_7 correlates with all axes of tactile sensations. Fonts with rough edges are selected for onomatopoeias meaning dry, hard and rough, such as Keba-Keba, Jyori-Jyori.

Tendency 3

The results of a comparative analysis of antonyms tend to indicate that each pair of antonyms shows opposite Z-score values. For example, if an onomatopoeia is related to a thin font, the antonym of the onomatopoeia will be related to a bold font. This tendency is confirmed in most FFQs.

Tendency 4

The phonological analysis results tend to indicate that the vowel and consonant in first mora of onomatopoeias correlate with the suitable font choice for each onomatopoeias. In particular, F_2 (line width), F_3 (circularity), and F_6 (aspect ratio) show this tendency.

6.2.4 Conclusion: onomatopoeias and fonts

This section described an analytical approach using FFQs. The aim of this analysis is to investigate the relationship between onomatopoeias and fonts based on appropriateness. The analysis results indicate that suitable fonts and these are affected from the phonemes that comprise the onomatopoeias and perceived meaning of the onomatopoeias.

For the onomatopoeias of emotions, the arousal-axis relates to line width, and each quadrant in arousal-valance space relates to the darkness of fonts. For the onomatopoeias of tactile sensations, the hardness-axis relates to the darkness of fonts, and all tactile sensations axes relate to the smoothness of fonts. In addition, the results of t-tests for each pair of antonyms indicate significant differences. Therefore, it is supposed that the meaning of onomatopoeias is affected by the choice of fonts and the impression created by a font. Furthermore, the results of the phonological analysis indicated that the vowel and consonant in first mora of onomatopoeias affect the impression created by fonts. In particular, phonemes correlate to the darkness or shape (circularity and aspect ratio) of fonts. Future work will investigate onomatopoeias categorized as other.

Chapter 7

Conclusion and future work

This chapter presents the conclusions of the investigations and analysis reported in the dissertation and describes future work. The first section presents a summary of the study, and the second section describes the contributions of this study to the fields of kansei study and knowledge science. The final section presents conclusions and suggestions for future work.

7.1 Summary

The main purpose of this study was to express kansei information. To achieve this purpose, this study focused on the effects of graphic design. On the basis of this focal point, this study adopted two approaches: (1) to support a graphic design work by utilizing graphic design effects, especially fonts, layout, and color, and (2) to investigate the effectiveness of onomatopoeias from the perspective of textual information. These two approaches aimed at providing support for utilization of graphic design elements.

7.1.1 Graphic design support methods

The first approach aims to support the handling of graphic design elements easily and effectively. This study proposed a graphic design support model using visual similarity and IEC. The proposed model was applied to the following graphic design elements: fonts, layout, and color. Most graphic design work uses these elements. Thus, this study proposed three graphic design support methods: a font search method, a grid layout generation method, and a color scheme search method.

The proposed IEC-based font search method provides a simple and effective font search process based on visual similarity. The experimental results indicated that this method was effective for searching a desired font and helping users obtain a font that is suitable for alphanumeric and Japanese (katakana, hiragana, and kanji) characters. In particular, this method demonstrated an advantage for operation time. The experimental results showed that operation time using the proposed search method was less than half or one-third the time required for a user to select a font from a font list.

The proposed IEC-based grid layout generation method allows users to obtain a desired grid layout easily and quickly in only a few operations. The experimental results showed that the proposed method produced grid layout candidates effectively. In addition, users obtained their desired grid layouts in less than 40 seconds. Furthermore, this method was implemented in a photo collage generating application.

The proposed IEC-based color scheme search method enables users to find a desired color scheme based on overall color scheme impressions. The experimental results confirmed that the proposed color scheme search method helped users to obtain a desired color scheme in less than 48 seconds. In addition, the proposed color scheme search method was implemented in a color transfer system. It was confirmed that the color transfer application provided users with desired recolored illustrations easily and quickly.

The experimental evaluations indicated that each proposed method was effective for concretizing a a user's mental image of a desired graphic design element. The results validate the practical effectiveness of the proposed support model. The proposed model has two features: visual similarity and concretization of a desired graphic design element. Visual similarity enables users to obtain desired graphic design elements; specialized graphic design knowledge or skills are not required. Furthermore, the concretization process allows users to refine the final version of their desired graphic design. These two advantageous features may contribute to the expression of human kansei information by utilizing the effects of graphic design.

7.1.2 Investigations of onomatopoeias

In the other approach, the aim was to investigate the effectiveness of onomatopoeias for expressing kansei information. This approach targeted textual information in graphic design by investigating the expression of emotions using onomatopoeias and the relationships between fonts and onomatopoeias. To investigate the effectiveness of onomatopoeias that convey human emotions as kansei media, a photography system and an image retrieval system were used to conduct experiments. The experimental results indicated that people did not remember specific emotions in detail; however, they did retain more general categories of emotion. These results indicate that onomatopoeias by emotion category can be utilized as kansei media to deal with emotions. In the investigation of the relationships among the appropriate combinations of fonts and onomatopoeias, the analyses confirmed that suitable fonts for onomatopoeias were relevant to the meaning of onomatopoeias and the phonemes that comprise onomatopoeic words.

7.2 Contributions

It is expected that the outcomes of the investigations conducted in this study will contribute to kansei study and knowledge science. This section discusses these contributions.

7.2.1 Kansei study

The development of information technologies is accelerating the diversification of knowledge. This development allows people to share and utilize knowledge all over the world. Furthermore, the sharing of knowledge produces new knowledge by combining or modifying different information. Moreover, there is vast amount of information on the Internet. Thus, information retrieval technologies are required to meet various demands. Kansei studies have proposed kansei searches that can find a user's preferred digital content [137, 138, 139, 140, 141]. These studies used a hierarchical model of visual perception processes. This model comprises four levels: physical, physiological, psychological, and cognitive levels. In this model, kansei represents the subjective evaluation criteria in a selection process.

This dissertation has presented three graphic design support methods. These methods have taken human evaluation into account. In an attempt to incorporate human evaluations in each method, each method defined visual similarity for each graphic design element. These visual similarities are related to subjective evaluation criteria, and each visual similarity considered human perceptions. In addition, the data structures of each method are related to human impressions. Several experimental results showed good performance. The analysis and results presented in this dissertation will contribute to improved kansei search models, particularly for physiological and psychological levels in the hierarchical model [141]. Kansei search is a challenging issue and various approaches have been reported [142, 143, 144, 145]. It is expected that the current study will contribute to ongoing kansei research.

7.2.2 Knowledge science

It is also expected that the methods reported in this study will provide an opportunity for novice user to learn about color and fonts. Even if a novice user reads a textbook about color, the creation of a desired color scheme may be difficult because they do not have sufficient practical experience. Generally, people who are just beginning to learn about color need to compare many colors to develop an individual aesthetic; therefore, this task may be discouraging. The proposed color scheme search method enables users to utilize many colors without any skills or knowledge of color. Thus, the proposed method supports beginner-level color design exercises. The same is true for the proposed font search method. Learning is significant for knowledge creation; therefore, the proposed support methods will contribute to graphic design knowledge creation.

This study analyzed the relationship between fonts and onomatopoeias using the font search method. A lot of data based on user kansei is required to apply the method; consequently, an efficient data collection method would need to be developed. In addition, the target data must include user kansei information. The proposed method reduces the cost of font selection and it enables each user to find their desired fonts based on their kansei. Therefore, this kansei-based approach has made it possible to undertake an effective and efficient analysis of the relationship between fonts and onomatopoeias based on kansei. All knowledge science involves human beings, and this kansei-based investigative approach could be applied to knowledge science research investigations.

In addition, this study supported to utilize graphic design elements. This outcome enables to facilitate kansei communication by the effect of graphic design. The expression of kansei information is a significant study approach for human communication; hence, it is expected that the outcome of this study will contribute knowledge science.

7.3 General conclusions and future work

This study focused on the effect of graphic design because it is a representative media for kansei information. This study has proposed a graphic design support model using visual similarity-based IEC, and the proposed model enables non-experts to select desired graphic design elements easily and effectively. This research outcome may allow people to express their kansei information via each graphic design element. Notably, the approaches and results reported here are the first phase of a longer ongoing study. In the current phase, it is impossible to utilize multiple elements simultaneously. In the next phase, combinations of graphic design elements will be considered. The experimental investigation of onomatopoeias has indicated relationships among the combinations of onomatopoeias and fonts. In future, additional experiments using the proposed graphic design support applications will be conducted. It is expected that these efforts will improve each graphic design support method. and thereby refine the overall proposed graphic design support model. Furthermore, the investigation of onomatopoeias is in a preliminary phase; hence, a great deal of experimentation associated with onomatopoeias is necessary from the perspective of textual information for kansei media.

In future, the combined system will facilitate deeper investigation of media representation. In addition, further discussions and investigations will clarify the effectiveness of onomatopoeias. In the proposed graphic design methods, the similarity of graphic design elements must be redefined to develop better support methods. This dissertation did not consider images such as paintings and illustrations as visual information. State-of-the-art algorithms [146, 147] that can be applied to drawings and paintings will enable users to create preferred renderings of their desired arts pieces. To achieve the representation of kansei information, image content is a significant element; thus, in future, the proposed model will target this area of study. Visual information abounds in various media, and if people can communicate their kansei easily via all media, people will be able to understand each other more intuitively and deeply.

The results presented in this dissertation anticipate visual expression of kansei.

References

[1] Saburo Tsuji. *Kansei Science*. SAIENSU, 1997. 1, 9

[2] Kenkichi Ishizuka, Shigeru Kato, and Takehisa Onisawa. Transformation of theme music based on impressions of stories generated from pictures. *Journal of Japan Society for Fuzzy Theory and Intelligent Informatics, (in Japanese)*, Vol. 19, No. 4, pp. 378 – 391, aug 2007. 1

[3] Ryo Hirae and Takashi Nishi. Mood classification of music audio signals. *The Journal of the Acoustical Society of Japan, (in Japanese)*, Vol. 64, No. 10, pp. 607 – 615, oct 2008. 1

[4] Yi-Hsuan Yang and Homer H. Chen. Machine recognition of music emotion: A review. *ACM Trans. Intell. Syst. Technol.*, Vol. 3, No. 3, pp. 40:1 – 40:30, may 2012. 1

[5] Keith Anderson and Peter W. McOwan. A real-time automated system for the recognition of human facial expressions. *Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactions on*, Vol. 36, No. 1, pp. 96 – 105, 2006. 1

[6] Usman Tariq, Kai-Hsiang Lin, Zhen Li, Xi Zhou, Zhaowen Wang, Vuong Le, Thomas S. Huang, Xutao Lv, and Tony X. Han. Recognizing emotions from an ensemble of features. *Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactions on*, Vol. 42, No. 4, pp. 1017 – 1026, 2012. 1

[7] Kagawa Kentaro, Itou Junko, and Munemori Jun. Effect of an intuitional pictogram comment function and an emotional sharing function for a video sharing web system. *IPSJ Journal, (in Japanese)*, Vol. 51, No. 3, pp. 770 – 783, mar 2010. 2, 3

[8] Yuichi Bannai, Masayuki Ishizawa, Hiroshi Shigeno, and Kenichi Okada. A communication model of scents mediated by sense-descriptive adjectives (user interfaces and interactive system). *IPSJ Journal, (in Japanese)*, Vol. 47, No. 12, pp. 3414 – 3422, dec 2006. 2

[9] Nimesha Ranasinghe, Ryohei Nakatsu, Hideaki Nii, and Ponnampalam Gopalakrishnakone. Tongue mounted interface for digitally actuating the sense of taste. In *Wearable Computers (ISWC), 2012 16th International Symposium on*, pp. 80 – 87, 2012. 2

[10] Ryohei Nakatsu, Makoto Tadenuma, and Tadao Maekawa. Computer technologies that support kansei expression using the body. In *Proceedings of the Ninth ACM International Conference on Multimedia*, MULTIMEDIA '01, pp. 358 – 364, New York, NY, USA, 2001. ACM. 2

[11] Hua Wang, Helmut Prendinger, and Takeo Igarashi. Communicating emotions in online chat using physiological sensors and animated text. In *CHI '04 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '04, pp. 1171–1174, New York, NY, USA, 2004. ACM. 2

[12] Ga-il Si and Hiroya Igarashi. Visual stimulus of icon and its context in non-verbal forms of communication : a comparative analysis with the icon in motion. In *Proceedings of the Annual Conference of JSSD, (in Japanese)*, No. 54, pp. 252 – 253. Japanese Society for the Science of Design, jun 2007. 3

[13] Chao Sun, Bing-Kun Bao, Changsheng Xu, and Tao Mei. Kinect-based visual communication system. In *Proceedings of the 4th International Conference on Internet Multimedia Computing and Service*, ICIMCS '12, pp. 55 – 59, New York, NY, USA, 2012. ACM. 3

[14] Hyun Hahm and Keun-Wang Lee. Visual communication methods of computer-generated images for making television graphics system. In *Computer Applications for Web, Human Computer Interaction, Signal and Image Processing, and Pattern Recognition*, Vol. 342, pp. 96 – 101. 2012. 3

[15] Masafusa Oohashi. *Oishii kankaku to kotoba shiyotsukan no sedai.* BMFT, 2010. 3

[16] Hideaki Chijiiwa. *Encyclopedia on color cognition of the world's youth.* Kawade Shobo Shinsha, (in Japanese), 1999. 8, 73

[17] Borut Zalik. An interactive constraint-based graphics system with partially constrained from features. In *Presse Universitaire de Namur*, pp. 129–139, 1996. 11, 25

[18] Jungpil Shin and Kazunori Suzuki. Interactive system for handwritten-style font generation. In *Computer and Information Technology, 2004. CIT '04. The Fourth International Conference on*, pp. 94–100, 2004. 11

[19] Yutaka Goda, Tsuyoshi Nakamura, and Masayoshi Kanoh. Texture transfer based on continuous structure of texture patches for design of artistic shodo fonts. In *ACM SIGGRAPH ASIA 2010 Sketches*, SA '10, pp. 18:1–18:2, New York, NY, USA, 2010. ACM. 11

[20] Vincent M. K. Lau. Learning by example for parametric font design. In *ACM SIGGRAPH ASIA 2009 Posters*, SIGGRAPH ASIA '09, pp. 5:1–5:1, New York, NY, USA, 2009. ACM. 11

[21] Rapee Suveeranont and Takeo Igarashi. Feature-preserving morphable model for automatic font generation. In *ACM SIGGRAPH ASIA 2009 Sketches*, pp. 7:1–7:1, 2009. 11

[22] Kaori Yoshida, Yuta Nakagawa, and Mario Kö andppen. Interactive genetic algorithm for font generation system. In *World Automation Congress (WAC), 2010*, pp. 1–6, 2010. 11, 25

[23] Akio Wada, Hajime Hotta, and Masafumi Hagiwara. A japanese font creating system reflecting user's kansei with various design functions. *Bulletin of Japanese Society for Science of Design, (in Japanese)*, Vol. 52, No. 6, pp. 9–16, mar 2006. 11

[24] Hajime Hotta, Takashi Nozawa, and Masafumi Hagiwara. An automatic japanese font designing system using kansei rule base. *IPSJ Journal, (in Japanese)*, Vol. 48, No. 3, pp. 1491–1501, mar 2007. iii, 11, 13

[25] Takashi Nozawa, Hajime Hotta, and Masafumi Hagiwara. A parameter extensible typeface definition method and its application to a font designing system. *The IEICE transactions on information and systems (in Japanese)*, Vol. J90–D, No. 10, pp. 2755–2764, 2007. 11, 25

[26] Tatsuo. Unemi and Megumi Soda. An iec-based support system for font design. In *Systems, Man and Cybernetics, 2003. IEEE International Conference on*, Vol. 1, pp. 968–973, 2003. 11

[27] Masaki Tode, Hiroaki Tanida, Tathuya Nakai, and Yushi Komachi. Functionalities of advanced supports for font selection and referencing. In *Proceedings of The 23th Meeting for Versatile Media Appliance of the Institute of Image Electoronics Engineers of Japan, (in Japanese)*, pp. 23–30, 2008. 13

[28] Martin Solli and Reiner Lenz. Fyfont: Find-your-font in large font databases. In *Image Analysis*, Vol. 4522 of *Lecture Notes in Computer Science*, pp. 432–441. Springer Berlin Heidelberg, 2007. iii, 13, 14

[29] Michael Patrick Cutter, Joost van Beusekom, Faisal Shafait, and

Thomas Michael Breuel. Unsupervised font reconstruction based on token co-occurrence. In *Proceedings of the 10th ACM symposium on Document engineering*, DocEng '10, pp. 143–150, New York, NY, USA, 2010. ACM. 13

[30] Saurabh Kataria, Lusa Marchesotti, and Florent Perronnin. Font retrieval on a large scale: An experimental study. In *Image Processing (ICIP), 2010 17th IEEE International Conference on*, pp. 2177–2180, 2010. 13

[31] C. Brian Atkins. Blocked recursive image composition. In *Proceedings of the 16th ACM international conference on Multimedia*, MM '08, pp. 821–824, New York, NY, USA, 2008. ACM. iii, 14, 15, 48, 49, 58, 60, 69

[32] Jun Xiao, Xuemei Zhang, Phil Cheatle, Yuli Gao, and C. Brian Atkins. Mixed-initiative photo collage authoring. In *Proceedings of the 16th ACM international conference on Multimedia*, MM '08, pp. 509–518, New York, NY, USA, 2008. ACM. 14, 48, 49, 58, 60, 65, 67, 69

[33] Carsten Rother, Lucas Bordeaux, Youssef Hamadi, and Andrew Blake. Autocollage. *ACM Trans. Graph.*, Vol. 25, No. 3, pp. 847–852, jul 2006. iii, 14, 16, 48, 58, 60, 69

[34] Jingdong Wang, Long Quan, Jian Sun, Xiaoou Tang, and Heung-Yeung Shum. Picture collage. In *Computer Vision and Pattern Recognition, 2006 IEEE Computer Society Conference on*, Vol. 1, pp. 347–354, 2006. iii, 14, 16, 48, 58, 60, 69

[35] Stas Goferman, Ayellet Tal, and Lihi Zelnik-manor. Puzzle-like collage. *Computer Graphics Forum*, Vol. 29, No. 2, pp. 459–468, 2010. iii, 14, 16, 48, 58

[36] Ying Cao, Antoni B. Chan, and Rynson W. H. Lau. Automatic stylistic manga layout. *ACM Trans. Graph.*, Vol. 31, No. 6, pp. 141:1–141:10, nov 2012. iii, 16, 17, 49, 60, 69

[37] Wei-Ta Chu and Hsing-Han Wang. Enabling portable animation browsing by transforming animations into comics. In *Proceedings of the 2nd ACM international workshop on Interactive multimedia on mobile and portable devices*, IMMPD '12, pp. 3–8, New York, NY, USA, 2012. ACM. iii, 16, 17, 60, 69

[38] Takamasa Tanaka, Kenji Shoji, Fubito Toyama, and Juichi Miyamichi. Layout analysis of tree-structured scene frames in comic images. In *Proceedings of the 20th international joint conference on Artifical intelligence*, IJCAI'07, pp. 2885–2890, San Francisco, CA, USA, 2007. Morgan Kauf-

mann Publishers Inc. 16

[39] Emi Myodo, Satoshi Ueno, Koichi Takagi, and Shigeyuki Sakazawa. Automatic comic-like image layout system preserving image order and important regions. In *Proceedings of the 19th ACM international conference on Multimedia*, MM '11, pp. 795–796, New York, NY, USA, 2011. ACM. 16, 48, 49, 60, 62, 69

[40] Shingo Uchihashi, Jonathan Foote, Andreas Girgensohn, and John Boreczky. Video manga: generating semantically meaningful video summaries. In *Proceedings of the seventh ACM international conference on Multimedia (Part 1)*, MULTIMEDIA '99, pp. 383–392, New York, NY, USA, 1999. ACM. 16

[41] Janko Calic, David P. Gibson, and Neill W. Campbell. Efficient layout of comic-like video summaries. *Circuits and Systems for Video Technology, IEEE Transactions on*, Vol. 17, No. 7, pp. 931–936, 2007. 16

[42] Connelly Barnes, Dan B. Goldman, Eli Shechtman, and Adam Finkelstein. Video tapestries with continuous temporal zoom. *ACM Trans. Graph.*, Vol. 29, No. 4, pp. 89:1–89:9, jul 2010. 16

[43] Charles Jacobs, Wilmot Li, Evan Schrier, David Bargeron, and David Salesin. Adaptive grid-based document layout. *ACM Trans. Graph.*, Vol. 22, No. 3, pp. 838–847, jul 2003. 17, 48

[44] Antoine Oliver, Nicolas Monmarche', and Gilles Venturini. Interactive design of web sites with a genetic algorithm. In *In Proceedings the IADIS International Conference WWW Internet*, pp. 355–362, 2002. 17, 48, 58

[45] Parry Moon and Domina Eberle Spencer. Geometric formulation of classical color harmony. *Journal of the optical society of america*, Vol. 34, No. 1, pp. 46–50, Jan 1944. 17

[46] Parry Moon and Domina Eberle Spencer. Area in color harmony. *Journal of the optical society of america*, Vol. 34, No. 2, pp. 93–103, Feb 1944. 17

[47] Parry Moon and Domina Eberle Spencer. Aesthetic measure applied to color harmony. *Journal of the optical society of america*, Vol. 34, No. 4, pp. 234–242, Apr 1944. 17

[48] Yutaka Matsuda. *Color Design*. Asakura Syoten, , (in Japanese), 1995. 17, 73, 79

[49] Shigenobu Kobayashi. *Color Image Scale*. Kodansha USA, 1992. 17, 73, 79

[50] Li-Chen Ou, M. Ronnier Luo, Andre Woodcock, and Angela Wright. A

study of colour emotion and colour preference. part i: Colour emotions for single colours. *Color Research & Application*, Vol. 29, No. 3, pp. 232–240, 2004. 17, 73

[51] Peter O'Donovan, Aseem Agarwala, and Aaron Hertzmann. Color compatibility from large datasets. *ACM Trans. Graph.*, Vol. 30, No. 4, pp. 63:1–63:12, jul 2011. 18, 79

[52] Sharon Lin and Pat Hanrahan. Modeling how people extract color themes from images. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '13, pp. 3101–3110, New York, NY, USA, 2013. ACM. 18

[53] Sharon Lin, Daniel Ritchie, Matthew Fisher, and Pat Hanrahan. Probabilistic color-by-numbers: suggesting pattern colorizations using factor graphs. *ACM Trans. Graph.*, Vol. 32, No. 4, pp. 37:1–37:12, jul 2013. iii, 18

[54] Yuichiro Kinoshita, Eric W. Cooper, Yukinobu Hoshino, and Katsuari Kamei. A townscape evaluation system based on kansei and colour harmony models. In *Systems, Man and Cybernetics, 2004 IEEE International Conference on*, Vol. 1, pp. 327–332, 2004. 19, 74

[55] Yuichiro Kinoshita, Yoshiaki Sakakura, Eric W. Cooper, Yukinobu Hoshino, and Katsuari Kamei. Townscape color planning system using an evolutionary algorithm and kansei evaluations. In *Fuzzy Systems, 2006 IEEE International Conference on*, pp. 931–938, 2006. 19, 74

[56] Daniel Cohen-Or, Olga Sorkine, Ran Gal, Tommer Leyvand, and Ying-Qing Xu. Color harmonization. *ACM Trans. Graph.*, Vol. 25, No. 3, pp. 624–630, jul 2006. 19, 79

[57] Xiaodi Hou and Liqing Zhang. Color conceptualization. In *Proceedings of the 15th international conference on Multimedia*, MULTIMEDIA '07, pp. 265–268, New York, NY, USA, 2007. ACM. 19

[58] Daniel Freedman and Pavel Kisilev. Object-to-object color transfer: Optimal flows and smsp transformations. In *Computer Vision and Pattern Recognition (CVPR), 2010 IEEE Conference on*, pp. 287–294, 2010. 19

[59] Baoyuan Wang, Yizhou Yu, Tien-Tsin Wong, Chun Chen, and Ying-Qing Xu. Data-driven image color theme enhancement. *ACM Trans. Graph.*, Vol. 29, No. 6, pp. 146:1–146:10, dec 2010. iii, 19

[60] Gabriela Csurka, Sandra Skaff, Luca Marchesotti, and Craig Saunders. Learning moods and emotions from color combinations. In *Proceedings of*

the Seventh Indian Conference on Computer Vision, Graphics and Image Processing, ICVGIP '10, pp. 298–305, New York, NY, USA, 2010. ACM. 19

[61] Naila Murray, Sandra Skaff, Luca Marchesotti, and Florent Perronnin. Towards automatic concept transfer. In *Proceedings of the ACM SIGGRAPH/Eurographics Symposium on Non-Photorealistic Animation and Rendering*, NPAR '11, pp. 167–176, New York, NY, USA, 2011. ACM. 19

[62] Naila Murray, Sandra Skaff, Luca Marchesotti, and Florent Perronnin. Toward automatic and flexible concept transfer. *Computers & Graphics*, Vol. 36, No. 6, pp. 622–634, 2012. iii, 19

[63] Masataka Tokumaru, Noriaki Muranaka, and Shigeru Imanishi. Color design support system considering color harmony. In *Fuzzy Systems, 2002. FUZZ-IEEE'02. Proceedings of the 2002 IEEE International Conference on*, Vol. 1, pp. 378–383, 2002. 20

[64] Masataka Tokumaru and Noriaki Muranaka. An evolutionary fuzzy color emotion model for coloring support systems. In *Fuzzy Systems, 2008. FUZZ-IEEE 2008. (IEEE World Congress on Computational Intelligence). IEEE International Conference on*, pp. 408–413, 2008. 20

[65] Hideki Yamazaki and Kunio Kondo. A method of changing a color scheme with kansei scales. *Journal for Geometry and Graphics*, Vol. 3, No. 1, pp. 77–84, 1999. 20

[66] Zhenyu Gu, Zhanwei Wu, Jiamin Yu, and Jian Lou. A color schemer for webpage design using interactive mood board. In Masaaki Kurosu, editor, *Human-Computer Interaction. Human-Centred Design Approaches, Methods, Tools, and Environments*, Vol. 8004 of *Lecture Notes in Computer Science*, pp. 555–564. Springer Berlin Heidelberg, 2013. 20

[67] Ryuichi Doizaki, Ai Oikawa, Yuichiro Shimizu, and Maki Sakamoto. Intuitive color design support system using onomatopoeia. In *Proceedings of the 5th International Congress of Design Research (IASDR 2013)*, No. 757–766, 2013. 20, 22

[68] Hiroyuki Inoue and Dan Yuan. Color coombination support systems using interactive genetic algorithms. *SCIS & ISIS*, Vol. 2008, pp. 486–490, 2008. 20, 73

[69] Hiroyuki Inoue, Dan Yuan, and Kae Iwatani. Color combination support systems using interactive evolutionary computation. *Journal of Japan Society for Fuzzy Theory and Intelligent Informatics, (in Japanese)*, Vol. 21,

No. 5, pp. 757–767, oct 2009. 20, 73, 88, 90

[70] Kensuke Tobitani, Kunihito Kato, and Kazuhiko Yamamoto. Research of color combination support based on individual kansei using interactive evolutionary computation. *The papers of Technical Meeting on The Institute of Electrical Engineers of Japan, (in Japanese)*, Vol. 2012, No. 1, pp. 49–54, mar 2012. 20, 73, 74

[71] Maiko Sugahara, Mitsunori Miki, and Tomoyuki Hiroyasu. Design of japanese kimono using interactive genetic algorithm. In *Systems, Man and Cybernetics, 2008. SMC 2008. IEEE International Conference on*, pp. 185–190, 2008. 20, 30, 73

[72] Fuyuko Ito, Tomoyuki Hiroyasu, Mitsunori Miki, and Hisatake Yokouchi. Offspring generation method for interactive genetic algorithm considering multimodal preference. *Transactions of the Japanese Society for Artificial Intelligence, (in Japanese)*, Vol. 24, No. 1, pp. 127–135, 2009. 20, 30, 73

[73] Mitsunori Miki, Noriko Okada, Tomoyuki Hiroyasu, and Masato Yoshimi. Office space design system using an interactive genetic algorithm. *The science and engineering review of Doshisha University, (in Japnese)*, Vol. 52, No. 3, pp. 241–222, 2011. 20, 73

[74] Shih-Wen Hsiao, Chiao-Fei Hsu, and Kai-Wei Tang. A consultation and simulation system for product color planning based on interactive genetic algorithms. *Color Research & Application*, Vol. 38, pp. 375–390, 2013. 20, 73

[75] Ikuhiro Tamori and Lawrence Schourup. *Onomatope: Keitai to imi*. Kuroshio Shuppan, (in Japanese), 1999. 20

[76] Eun-Ah Lee. *A contrastive study on Japanese and Korean onomatopoeia, (in Japanese)*. PhD thesis, Nagoya university, 2000. 20

[77] Kenichi Kadooka. An etymological study of the japanese onomatopoeia lexicon. In *The ryukoku international center research bulletin, (in Japanese)*, 2004. 20

[78] Jun Otomasa. *Doitugo-onomatope-no kenkyuu: Sono onso-doonyuu-keiki-to onso-hairetu-genri [Studien zu deutschen Onomatopoetika: Bildung und Ordnung der Phonemketten]*. Daigaku Shorin, (in Japanese), 2009. 20

[79] Takanori Komatsu. Quantifying japanese onomatopoeias: toward augmenting creative activities with onomatopoeias. In *Proceedings of the 3rd Augmented Human International Conference*, AH '12, pp. 15:1–15:4, New York, NY, USA, 2012. ACM. 20

[80] Yoshitaka Fujino, Inoue Kousei, Masao Kikkawa, Emi Nishina, and Tsuneo Yamada. Development and evaluation of sport onomatopoeia computerized dictionary for motor learning. *Japan journal of educational technology, (in Japanese)*, Vol. 29, No. 4, pp. 515–525, 2006. 21, 94, 101

[81] Mariko Udo and Miyuki Takano. Onomatopoeic utterances in classes at an elementary school for handicapped children: linguistic effects on activation of communicative behavior. *The Journal of school education, (in Japanese)*, Vol. 19, pp. 17–26, 2007. 21, 94, 101

[82] Kohske Takahashi, Hideo Mitsuhashi, Shin Norieda, Mitsuru Sendoda, Kazuhiro Murata, and Katsumi Watanabe. Japanese onomatopoeias and sound symbolic words describing. *Technical report of IEICE. HCS, (in Japanese)*, Vol. 109, No. 224, pp. 11–16, oct 2009. 21

[83] Kohske Takahashi, Hideo Mitsuhashi, Kazuhiro Murata, Shin Norieda, and Katsumi Watanabe. Kansei information and factor space of nonverbal interpersonal communicaion - psychological investigation on physical contacts modified by japanese onomatopoieas -. *Transactions of Japan Society of Kansei Engineering, (in Japanese)*, Vol. 10, No. 2, pp. 261 – 268, 2011. 21

[84] Takanori Komatsu and Hiromi Akiyama. Expression system of onomatopoeias for assisting users' intuitive expressions. *The Transactions of the Institute of Electronics, Information and Communication Engineers. A, (in Japanese)*, Vol. 92, No. 11, pp. 752 – 763, nov 2009. 22

[85] Yutaro Tomoto, Tsuyoshi Nakamura, Masayoshi Kanoh, and Takanori Komatsu. Visualization of onomatopoeia based on phonemic features. *Transactions of Japan Society of Kansei Engineering, (in Japanese)*, Vol. 11, No. 4, pp. 545 – 552, 2012. 22

[86] Tomohiko Hayakawa, Shigeru Matsui, and Junji Watanabe. Classification method of tactile textures using onomatopoeias. *Transactions of the Virtual Reality Society of Japan, (in Japanese)*, Vol. 15, No. 3, pp. 487–490, sep 2010. 22, 103, 104, 105, 114

[87] Junji Watanabe and Maki Sakamoto. Comparison between onomatopoeias and adjectives for evaluating tactile sensatoins. In *Soft Computing and Intelligent Systems (SCIS) and 13th International Symposium on Advanced Intelligent Systems (ISIS), 2012 Joint 6th International Conference on*, No. 2346–2348, 2012. 22

[88] Yuya Ueda, Yuichiro Shimizu, and Maki Sakamoto. System construction

supporting communication with foreign doctors using onomatopoeia expressing pains. In *Soft Computing and Intelligent Systems (SCIS) and 13th International Symposium on Advanced Intelligent Systems (ISIS), 2012 Joint 6th International Conference on*, pp. 508–512, 2012. 22

[89] Keisuke Kambara and Koji Tsukada. Onomatopen: painting using onomatopoeia. In *Proceedings of the 9th international conference on Entertainment computing*, ICEC'10, pp. 43–54, Berlin, Heidelberg, 2010. Springer-Verlag. 22

[90] Chiemi Watanabe and Satoshi Nakamura. Onomatoperori: search engine for cooking recipes by impression of their tastes or textures using japanese onomatopoeia. In *Soft Computing and Intelligent Systems (SCIS) and 13th International Symposium on Advanced Intelligent Systems (ISIS), 2012 Joint 6th International Conference on*, No. 2349–2350, 2012. 22

[91] Ayumi Kato, Yusuke Fukazawa, Tomomasa Sato, and Taketoshi Mori. Extraction of onomatopoeia used for foods from food reviews and its application to restaurant search. In *Proceedings of the 21st international conference companion on World Wide Web*, WWW '12 Companion, pp. 719–728, New York, NY, USA, 2012. ACM. 22

[92] Paul W. H. Kwan and Junbin Gao. A multi-step strategy for approximate similarity search in image databases. In *Proceedings of the 17th Australasian Database Conference*, Vol. 49, pp. 139–147, 2006. 25

[93] Kazuo Shibuta. A difference of psychological evaluation structure by display media. In *Proceedings of The 56th Annual Conference of Japanese Society for the Science of Design, (in Japanese)*, pp. 294–295, 2009. 26

[94] Michio Shiraishi and Yasushi Yamaguchi. An algorithm for automatic painterly rendering based on local source image approximation. In *Proceedings of the 1st international symposium on Non-photorealistic animation and rendering*, pp. 53–58, 2000. 28

[95] Nobuyuki Otsu and Takio Kurita. A new scheme for practical flexible and intelligent vision systems. In *Proceedings of the IAPR Workshop on Computer Vision*, pp. 431–435, 1988. 29

[96] Michel J. Swain and Dana H. Ballard. Color indexing. *International journal of computer vision*, Vol. 7, pp. 11–32, 1991. 30

[97] Yoichiro Maeda and Shigeru Miyashita. Chaotic interactive sound generation system using interactive genetic algorithm. *Journal of Japan Society for Fuzzy Theory and Intelligent Informatics, (in Japanese)*, Vol. 21,

No. 5, pp. 768–781, 2009. 30

[98] Yoichiro Maeda and Yusuke Kajihara. Rhythm generation method for automatic musical composition using genetic algorithm. In *Fuzzy Systems (FUZZ), 2010 IEEE International Conference on*, pp. 1–7, 2010. 30

[99] Junki Hakamata, Yuta Tokumi, and Masataka Tokumaru. A framework of recommender system using interactive evolutionary computation. *Transactions of Japan Society of Kansei Engineering, (in Japanese)*, Vol. 11, No. 2, pp. 281–288, 2012. 30

[100] Tsuyoshi Nakamura, Masahiro Haruta, Yuyan Chao, and Hidenori Itoh. Color transfer between images using interactive evolutionary computation. *Journal of Japan Society for Fuzzy Theory and Intelligent Informatics, (in Japanese)*, Vol. 17, No. 3, pp. 376–385, 2005. 31

[101] Tokihiro Kimura, Hidehiro Ohki, Kiyokazu Ueda, Yutaka Fujiki, and Naomichi Sueda. An parameter search method in image processing system based on candidate image selection by user. *Information Processing Society of Japan (IPSJ) Journal, (in Japanese)*, Vol. 290, No. 22, pp. 2319–2323, 2008. 32, 54, 78

[102] Joshua B. Tnenbaum, Vin de Silva, and John C. Langford. A global geometric framework for nonlinear dimensionality reduction. *SCIENCE*, Vol. 290, No. 22, pp. 2319–2323, 2000. 42

[103] Juan C. Quiroz, Sushil J. Louis, Anil Shankar, and Sergiu M. Dascalu. Interactive genetic algorithms for user interface design. In *IEEE Congress on Evolutionary Computation (CEC'07)*, pp. 1366–1373, 2007. 48

[104] Stephen B. Chisholm, Dirk V. Arnold, and Stephen Brooks. Tone mapping by interactive evolution. In *Proceedings of the 11th Annual conference on Genetic and evolutionary computation*, GECCO '09, pp. 515–522, New York, NY, USA, 2009. ACM. 48

[105] Steve R. Bergen. Evolving stylized images using a user-interactive genetic algorithm. In *Proceedings of the 11th Annual Conference Companion on Genetic and Evolutionary Computation Conference: Late Breaking Papers*, GECCO '09, pp. 2745–2752, New York, NY, USA, 2009. ACM. 48

[106] Ken Ishibashi and Kazunori Miyata. Font selection using an interactive genetic algorithm and similarity search. In *Proceeding of IWAIT2012*, Vol. 9, pp. 494–499, 2012. 48

[107] Tatsuo Unemi. Sbart 2.4: an iec tool for creating 2d images,. In *Proceedings of 2000 Genetic and Evolutionary Computational Conference Work-*

shop Program, pp. 153–155, 2000. 48, 53

[108] Qinying Xu, Daryl D'Souza, and Vic Ciesielski. Evolving images for entertainment. In *Proceedings of the 4th Australasian conference on Interactive entertainment*, No. 1–8 in IE '07, pp. 26:1–26:8, Melbourne, Australia, Australia, 2007. RMIT University. 48, 53

[109] Ma Jingye and Hideyuki Takagi. Design of composite image filters using interactive genetic programming. In *Innovations in Bio-Inspired Computing and Applications (IBICA), 2012 Third International Conference on*, pp. 274–279, 2012. 48, 53

[110] Riccardo Poli and William B. Langdon. On the search properties of different crossover operators in genetic programming. In John R. Koza, Wolfgang Banzhaf, Kumar Chellapilla, Kalyanmoy Deb, Marco Dorigo, David B. Fogel, Max H. Garzon, David E. Goldberg, Hitoshi Iba, and Rick Riolo, editors, *Genetic Programming 1998: Proceedings of the Third Annual Conference*, pp. 293–301, University of Wisconsin, Madison, Wisconsin, USA, 22-25 1998. Morgan Kaufmann. 54

[111] Peter A. Whigham and Grant Dick. Implicitly controlling bloat in genetic programming. *Evolutionary Computation, IEEE Transactions on*, Vol. 14, No. 2, pp. 173–190, 2010. 55

[112] L. Itti, C. Koch, and E. Niebur. A model of saliency-based visual attention for rapid scene analysis. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, Vol. 20, No. 11, pp. 1254–1259, 1998. 60

[113] Ming-Ming Cheng, Guo-Xin Zhang, N. J. Mitra, Xiaolei Huang, and Shi-Min Hu. Global contrast based salient region detection. In *Proceedings of the 2011 IEEE Conference on Computer Vision and Pattern Recognition*, CVPR '11, pp. 409–416, Washington, DC, USA, 2011. IEEE Computer Society. 60

[114] Robert B. Zajonc. Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology*, Vol. 9, pp. 1–27, 1968. 68

[115] Luigi Troiano, Cosimo Birtolo, and Gennaro Chirillo. Interactive genetic algorithm for choosing suitable colors in user interface. In *In proceedings of Learning and Intelligent OptimizatioN, LION3*, pp. 14 – 18, 2009. 74

[116] Eva Lübbe. *Colours in the Mind - Colour Systems in Reality*. BoD, 2010. 74

[117] Gaurav Sharma, Wencheng Wu, and Edul N. Dalal. The ciede2000 color-difference formula: Implementation notes, supplementary test data, and

mathematical observations. *Color Research & Application*, Vol. 30, No. 1, pp. 21–30, 2005. 82

[118] Kunio Kondo, Masahiro Takahashi, Masanao Matsunaga, and Hideki Yamazaki. A kansei method for retrieving images from a database using colors. *The journal of the Institute of Image Information and Television Engineers, (in Japanese)*, Vol. 54, No. 11, pp. 1615–1622, nov 2000. 84, 97

[119] Jennifer. M. Cox and Alastair Davison. The visual analogue scale as a tool for self reporting of subjective phenomena in the medical radiation. *The Radiographer*, Vol. 52, pp. 22–24, 2005. 85

[120] Ulf-Dietrich Reips and Frederik Funke. Interval-level measurement with visual analogue scales in internet-based research: Vas generator. *Behavior research methods*, Vol. 40, No. 3, pp. 699–704, 2008. 85

[121] Shinya Takahashi and Takashi Hanari. Cognitive factors in color preference. *Journal of the Color Science Association of Japan, (in Japanese)*, Vol. 29, No. 1, pp. 14–23, mar 2005. 85

[122] Satoshi Watanabe and Yuji Matsumoto. An analysis of information skills for students based on a visual analog scale. *Journal of Biomedical Fuzzy Systems Association, (in Japanese)*, Vol. 13, No. 1, pp. 57–62, jun 2011. 85

[123] Reisis Likert. A technique for the measurement of attitudes. *Archives of Psychology*, Vol. 22, No. 140, 1932. 85

[124] Shigenobu Kobayashi. *Art of color combinations*. Kodansha International, 1995. 86

[125] Roger Brown and James Kulik. Flashbulb memories. *Cognition*, Vol. 5, No. 1, pp. 73 – 99, 1977. 93

[126] Ken Ishibashi and Kazunori Miyata. Feasibility study on embedding emotions in images by color effects. In *Proceedings of Forum on Information Technology 2010, (in Japanese)*, Vol. 9, pp. 529–530. Forum on Information Technology, aug 2010. 94

[127] Masahiro Ono. *Japanese onomatopoeia dictionary*. Shougakukan, (in Japanese), 2007. 95, 103

[128] Tsuyoshi Moriyama, Hideo Saito, and Shinji Ozawa. Evaluation of the relation between emotional concepts and emotional parameters in speech. *The transactions of the Institute of Electronics, Information and Communication Engineers. D-II, (in Japanese)*, Vol. 82, No. 4, pp. 703–711,

apr 1999. 96

[129] Bjorn Schuller, Bogdan Vlasenko, Florian Eyben, Martin Wollmer, Andre Stuhlsatz, Andreas Wendemuth, and Gerhard Rigoll. Cross-corpus acoustic emotion recognition: Variances and strategies. *Affective Computing, IEEE Transactions on*, Vol. 1, No. 2, pp. 119–131, 2010. 96

[130] Chung-Hsien Wu and Wei-Bin Liang. Emotion recognition of affective speech based on multiple classifiers using acoustic-prosodic information and semantic labels. *Affective Computing, IEEE Transactions on*, Vol. 2, No. 1, pp. 10–21, 2011. 96

[131] Haruhiko Nishiyama and Yutaka Matsushita. An image retrieval system considering image composition. *IPSJ Journa, (in Japanese)*, Vol. 37, No. 1, pp. 101–109, jan 1996. 97

[132] Hendrik O. Knoche, John D. McCarthy, and M. Angela Sasse. Reading the fine print: the effect of text legibility on perceived video quality in mobile tv. In *Proceedings of the 14th annual ACM international conference on Multimedia*, MULTIMEDIA '06, pp. 727–730, New York, NY, USA, 2006. ACM. 102

[133] Jean-Luc Vinot and Sylvie Athenes. Legible, are you sure?: an experimentation-based typographical design in safety-critical context. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, pp. 2287–2296, New York, NY, USA, 2012. ACM. 102

[134] Ying Li and Ching Y. Suen. Typeface personality traits and their design characteristics. In *Proceedings of the 9th IAPR International Workshop on Document Analysis Systems*, DAS '10, pp. 231–238, New York, NY, USA, 2010. ACM. 102

[135] Toshihiko Amemiya and Satohide Mizutani. On the basic affective dimensions of japanese onomatopoeia and the basic level of japanese phonesthemes (explorations in affective science). *Bulletin of the Faculty of Sociology, Kansai University, (in Japanese)*, Vol. 37, No. 2, pp. 139–166, mar 2006. 103

[136] Peter. J. Lang. The emotion probe: Studies of motivation and attention. *American psychologist*, Vol. 50, pp. 372–372, 1995. 104

[137] Akihiro Ogino and Toshikazu Kato. Kansei kobo: Experiment system for design and prototyping of kansei retrieval algorithms. *Journal of Japan Society of Kansei Engineering, (in Japanese)*, Vol. 5, No. 3, pp. 71–80, 2005. 118

[138] Akihiro Ogino and Toshikazu Kato. Kansei system modeling : Design method for kansei retrieval systems. *IPSJ Journal, Database, (in Japanese)*, Vol. 47, No. 4, pp. 28–39, mar 2006. 118

[139] Masahiro Tada and Toshikazu Kato. Visual impression modeling using svm for automatic image classification. In *Systems, Man and Cybernetics, 2006. SMC '06. IEEE International Conference on*, Vol. 1, pp. 872–877, 2006. 118

[140] Masahiro Tada and Toshikazu Kato. Visual kansei modeling based on focal area analysis and hierarchical classification. *Systems and Computers in Japan*, Vol. 38, No. 13, pp. 58–71, 2007. 118

[141] Toshikazu Kato. Kansei engineering for advanced image media service. *Journal of the Imaging Society of Japan, (in Japanese)*, Vol. 47, No. 3, pp. 183–188, 2008. 118, 119

[142] Manabu Fukuda, Kaoru Sugita, and Yoshitaka Shibata. Perceptional retrieving method for distributed design image database system. *IPSJ Journal*, Vol. 39, No. 2, pp. 158–169, feb 1998. 119

[143] Takashi Mitsuishi, Jun Sasaki, and Yutaka Funyu. A design of a kansei retrieval system for distributed multimedia databases. In *Information Networking, 2001. Proceedings. 15th International Conference on*, pp. 285–290, 2001. 119

[144] Daichi Okunaka and Masataka Tokumaru. Kansei retrieval model using a neural network. *Transactions of Japan Society of Kansei Engineering, (in Japanese)*, Vol. 11, No. 2, pp. 331–338, 2012. 119

[145] Takaki Urai, Daichi Okunaka, and Masataka Tokumaru. Clothing image retrieval based on a similarity evaluation method for kansei retrieval system. In *Soft Computing and Intelligent Systems (SCIS) and 13th International Symposium on Advanced Intelligent Systems (ISIS), 2012 Joint 6th International Conference on*, pp. 261–265, 2012. 119

[146] Yong Jae Lee, C. Lawrence Zitnick, and Michael F. Cohen. Shadowdraw: Real-time user guidance for freehand drawing. *ACM Trans. Graph.*, Vol. 30, No. 4, pp. 27:1 – 27:10, jul 2011. 120

[147] Jan Eric Kyprianidis, John Collomosse, Tinghuai Wang, and Tobias Isenberg. State of the árt́ A taxonomy of artistic stylization techniques for images and video. *IEEE Transactions on Visualization and Computer Graphics*, Vol. 19, No. 5, pp. 866 – 885, 2013. 120

A

Supplementary information: font search method

A.1 Details of initial parameters

The IGA of the proposed font search method has two initial parameters: “Weight” and “Balance.” The weight parameter has three options: “Random,” “Heavy,” and “Light.” The balance parameter also has three options: “Random,” “Good,” and “Bad.” Each font of an initial population is determined by a probability of being selected from a font database. Font ID i, the probability P_i^* is defined as follows:

$$P_i^* = \frac{1}{2}\left(\frac{A_i}{\sum_{j=1}^{N^*} A_j} + \frac{B_i}{\sum_{j=1}^{N^*} B_j}\right), \tag{A.1}$$

$$A_i = \begin{cases} 1 & (Weight = Random) \\ a_i^{\kappa} & (Weight = Heavy) \\ (1-a_i)^{\kappa} & (Weight = Light) \end{cases}$$

$$B_i = \begin{cases} 1 & (Balance = Random) \\ b_i^{\kappa} & (Balance = Good) \\ (1-b_i)^{\kappa} & (Balance = Bad) \end{cases}$$

$$a_i = \frac{1}{2}\left(\frac{\left|F_1^{max} - F_1(i)\right|}{F_1^{max} - F_1^{min}} + \frac{\left|F_2^{min} - F_2(i)\right|}{F_2^{max} - F_2^{min}}\right)$$

$$b_i = \frac{1}{2}\left(\frac{|45 - F_5(i)|}{45} + \frac{|100 - F_6(i)|}{50}\right)$$

Here, F_n^{max} and F_n^{min} are the maximum and minimum values of the n th FFQ respectively, and $F_n(i)$ is a value of the n th FFQ for a font of ID i. The angle value F_5 of the balance parameter does not distinguish right from left. Thus, in the case of $F_5(i) > 90$, it is calculated as $F_5(i) = 180 - F_5(i)$ in the range $[0, 90]$. a_i and b_i denote the averages of the differences from the extremum or the criterion value. κ is a weight parameter for the enhancement of this initial parameter setting. Note that N^* is the number of all fonts in a database, and this study set $\kappa = 5$. A_i and B_i return different values for each user-specified option.

A.2 Font list

The experimental evaluations of this study used 1360 alphabet fonts, 370 katakana and hiragana fonts, and 250 kanji fonts. Tables A.1–A.5 show the 1360 alphabet fonts. Tables A.6 and A.7 show the 370 katakana and hiragana fonts and the 250 kanji fonts, respectively.

Table A.1 Font list 1 (alphabet)

Agency FB	Aharoni	Algerian
Andalus	Angsana New	AngsanaUPC
Aparajita	Arabic Typesetting	Arial
Arial Black	Arial Narrow	Arial Rounded MT Bold
Arial Unicode MS	Baskerville Old Face	Batang
BatangChe	Bauhaus 93	Bell MT
Berlin Sans FB	Berlin Sans FB Demi	Bernard MT Condensed
Blackadder ITC	Bodoni MT	Bodoni MT Black
Bodoni MT Condensed	Bodoni MT Poster Compressed	Book Antiqua
Bookman Old Style	Bradley Hand ITC	Britannic Bold
Broadway	Browallia New	BrowalliaUPC
Brush Script MT	Calibri	Californian FB
Calisto MT	Cambria	Candara
Castellar	Centaur	Century
Century Gothic	Century Schoolbook	Chiller
Colonna MT	Comic Sans MS	Consolas
Constantia	Cooper Black	Copperplate Gothic Bold
Copperplate Gothic Light	Corbel	Cordia New
CordiaUPC	Courier New	Curlz MT
DaunPenh	David	DFKai-SB
DilleniaUPC	DokChampa	Dotum
DotumChe	Ebrima	Edwardian Script ITC
Elephant	Engravers MT	Eras Bold ITC
Eras Demi ITC	Eras Light ITC	Eras Medium ITC
Estrangelo Edessa	EucrosiaUPC	Euphemia
FangSong	Felix Titling	Footlight MT Light
Forte	Franklin Gothic Book	Franklin Gothic Demi
Franklin Gothic Demi Cond	Franklin Gothic Heavy	Franklin Gothic Medium
Franklin Gothic Medium Cond	FrankRuehl	FreesiaUPC
Freestyle Script	French Script MT	Gabriola
Garamond	Gautami	Georgia
Gigi	Gill Sans MT	Gill Sans MT Condensed
Gill Sans MT Ext Condensed Bold	Gill Sans Ultra Bold	Gill Sans Ultra Bold Condensed
Gisha	Gloucester MT Extra Condensed	Goudy Old Style
Goudy Stout	Gulim	GulimChe
Gungsuh	GungsuhChe	Haettenschweiler
Harlow Solid Italic	Harrington	HGP 創英角 UB
HGP 創英角体	HGP 創英 EB	HGP 教科書体
HGP 明朝 B	HGP 明朝 E	HGP 行書体
HGPE	HGPM	HGS 創英角 UB
HGS 創英角体	HGS 創英 EB	HGS 教科書体
HGS 明朝 B	HGS 明朝 E	HGS 行書体
HGSE	HGSM	HG 丸 M-PRO
HG 創英角 UB	HG 創英角体	HG 創英 EB
HG 教科書体	HG 明朝 B	HG 明朝 E
HG 正楷書体-PRO	HG 行書体	HGE
HGM	High Tower Text	Impact
Imprint MT Shadow	Informal Roman	IrisUPC
Iskoola Pota	JasmineUPC	Jokerman
Juice ITC	KaiTi	Kalinga
Kartika	Khmer UI	KodchiangUPC
Kokila	Kristen ITC	Kunstler Script
Lao UI	Latha	Leelawadee
Levenim MT	LilyUPC	Lucida Bright
Lucida Calligraphy	Lucida Console	Lucida Fax
Lucida Handwriting	Lucida Sans	Lucida Sans Typewriter
Lucida Sans Unicode	Magneto	Maiandra GD
Malgun Gothic	Mangal	Matura MT Script Capitals
Meiryo UI	Microsoft Himalaya	Microsoft JhengHei
Microsoft New Tai Lue	Microsoft PhagsPa	Microsoft Sans Serif
Microsoft Tai Le	Microsoft Uighur	Microsoft YaHei
Microsoft Yi Baiti	MingLiU	MingLiU-ExtB
MingLiU_ HKSCS	MingLiU_ HKSCS-ExtB	Miriam
Miriam Fixed	Mistral	Modern No. 20
Mongolian Baiti	Monotype Corsiva	MoolBoran
MS Reference Sans Serif	MS UI Gothic	MV Boli
Narkisim	Niagara Engraved	Niagara Solid
NSimSun	Nyala	OCR A Extended
OCRB	Old English Text MT	Onyx
Palace Script MT	Palatino Linotype	Papyrus
Perpetua	Perpetua Titling MT	Plantagenet Cherokee
Playbill	PMingLiU	PMingLiU-ExtB
Poor Richard	Pristina	Raavi
Rage Italic	Ravie	Rockwell
Rockwell Condensed	Rockwell Extra Bold	Rod
Sakkal Majalla	Script MT Bold	Segoe Print
Segoe Script	Segoe UI	Segoe UI Light
Segoe UI Semibold	Segoe UI Symbol	Shonar Bangla
Showcard Gothic	Shruti	SimHei
Simplified Arabic	Simplified Arabic Fixed	SimSun
SimSun-ExtB	Snap ITC	Stencil
Sylfaen	Symbol	Tahoma
Tempus Sans ITC	Times New Roman	Traditional Arabic
Trebuchet MS	Tunga	Tw Cen MT
Tw Cen MT Condensed	Tw Cen MT Condensed Extra Bold	Utsaah
Vani	Verdana	Vijaya
Viner Hand ITC	Vivaldi	Vladimir Script
Vrinda	Wide Latin	メイリオ
ＭＳ ゴシック	ＭＳ 明朝	ＭＳ Ｐゴシック
ＭＳ Ｐ明朝	Adams	Adams Condensed
Adams Extended	Adams Thin	Adams Wide

Table A.2 Font list 2 (alphabet)

Advantage Book	Advantage Demi	Aidan
Aidan Thin	Akron	Alan
Aljo	Almagro	Aloe
Aloe Extended	Aloe Thin	Alor
Alor Condensed	Alor Narrow	Alor Narrow Cond
Alor Narrow Wide	Alor Wide	Alps
Alps Condensed	Alps Extended	Alps Thin
Alps Wide	Alton	Amaze
Amaze D	Ameretto	Ameretto Condensed
Ameretto Extended	Ameretto Thin	Ameretto Wide
Amery	Amery Condensed	Amery Extended
Amery Thin	Amery Wide	Amherst
Amos	Amos Extended	Amos Thin
Andres	Ankeny	Anne
Annual	Annual Condensed	Annual Extended
Annual Thin	Annual Wide	Antique
Antique2	Arbor	Architect
Armour	Array	Array Condensed
Array Extended	Array Thin	Array Wide
Artisan	Asa	Asia
Asia Extended	Asia Thin	Atilla
Atilla Condensed	Atilla Extended	Atilla Thin
Atilla Wide	Bade	Badger
Balloon	Banco	Bangle
Bangle Condensed	Bangle Extended	Bangle Thin
Bangle Wide	Banner	Banner Lite
Banty	Banty S	Barrett
Barrett Condensed	Barrett Extended	Barrett Thin
Barrett Wide	Barron	Bart
Bart Heavy	Bart Thin	Bart Thin Heavy
Basha	Basing	Basque
Basque Thin	Bassett	Bassett H
Bassett Thin	Bazooka	Beach
Beach Condensed	Beach Extended	Beach Thin
Beach Wide	Beagle	Beagle Condensed
Beagle Extended	Beau	Beau Cond
Beau Thin	Bendix	Benito
Bernhart	Bernie	Bernie Condensed
Bert	Bid Rom Thin	Bid Rom Wide
Bid Roman	Bid Roman Cond	Bid Roman Ext
Billboard	Billboard 11	Billboard 11 Condensed
Billboard 11 Wide	Bimini	Bimini Condensed
Bimini Wide	Birdlak	Blacksmith
Blew	Blew Condensed	Blew Extended
Blew Thin	Blew Wide	Bliss
Bliss Condensed	Bliss Extended	Bliss Thin
Bliss Wide	Block	Block Condensed
Block Wide	Bobbo	Bobcat
Bobo	Bobo Thin	Bobz
Boods	Bosnia	Bosnia Demi
Bosnia Extended	Bosnia Thin	Bosnia Wide
Boulder	Bow	Bowfin
Boyken	Brad	Brando
Brando Condensed	Brando Engraved	Brando Engraved Cond
Brightn	Brion	Brisk
Brisk D Thin	Brisk Extended	Brisk Thin
Broach	Broach Thin	Broadcast
Brown	Brush Stroke 26	Brushstroke 35
Bully	Bully Narrow	Burlesque
Busso	Busso Narrow	Busso Wide
Button	Byfield	Cable
Cable Thin	Calli 109	CalligrapherRegular
Cally 721	Cameron	Candide Narrow
Cane	Cane Condensed	Cane Hollow
Carla	Carla Thin	Carlos
Carmine	Carmine Condensed	Carmine Wide
Carnes	Cartoon	Casey
Castle	Catchup	Catchup Thin
Celebrity	Centaur	Cento
Cento Condensed	Cento Extended	Cento Thin
Cento Wide	Cerebral	CezanneRegular
Challenge	Challenge Condensed	Challenge Extended
Challenge Thin	Challenge Wide	Chancellor
Chaney	Chaney Extended	Chaney Thin
Chaney Wide	Chapman	Charles
Chas	Chasm	Chasm Ext Heavy
Chasm Extended	Chasm Thin	Chaucer
Chaz	Chaz Condensed	Chaz Extended
Chaz Thin	Chaz Wide	Chelsey
Chelsey Condensed	Chelsey Extended	Chelsey Thin
Chelsey Wide	Chipper	Chisel
Chisel Condensed	Chisel Extended	Chisel Thin
Chisel Wide	Chris	Christa
Christie	Chuckie	Circus
Circus Thin	Circus Wide	Civilian
Clare	Clare Condensed	Clare Extended
Clare Thin	Clare Wide	Clarxn
Clayton	Clayton Condensed	Clayton Extended
Clayton Thin	Clayton Wide	Clean
Clean Condensed	Clean Wide	Clyde
Cobalt	Cobalt Condensed	Cobalt Extended

Table A.3 Font list 3 (alphabet)

Cobalt Thin	Cobalt Wide	Cobb
Cocoa	Cocoa Thin	Cocoa Wide
Cody	Commador	Commador Ext
Commador Ext Heavy	Commador Heavy	Commador Wide
Commador Wide Heavy	Congo	Congo Condensed
Congo Ext	Congo Thin	Congo Wide
ContinuumBold	ContinuumLight	ContinuumMedium
Cool	Corbitt	Cordial
Cornerstone	Covey	Cowboy
Cowboy Thin	Crate	Crest
Crest Heavy	Crest Thin	Crest Thin Heavy
Crystal	Cuckoo	Cupid
Cupid Condensed	Cupid Wide	Curtis
Dado	Dakota	Dana
Daniel	Danto	Danto Lite
Danto Thin	Dart	Dave
Davis	Dawson	Debbijo
Dells	DenmarkRegular	Dennis
Derby	Devil	Devil Heavy
Devil Medium	Devine	Devine Condensed
Devine Wide	Di	Di Narrow
Digital	Dik	Diner
Dino	Dlnfont	Dolphin
Dolphin Condensed	Dolphin Extended	Dolphin Thin
Dolphin Wide	Dom	Dominon
Dominon Lite	Douglas	Downtown
Downtown Thin	Downtown Wide	Duchess
Duke	Duke Condensed	Duke Extended
Duke Thin	Duke Wide	Dunsay
Eddie	Editor	Editor Cndn
Edward	Eggo	Eggo Condensed
Eggo Extended	Eggo Thin	Eggo Wide
Elephant	Elephant Cond	Elephant Extended
Elephant Thin	Elephant Wide	Emerald Isle
Empire	Enchanted	Encino
Encino Condensed	Encino Extended	Encino Wide
Encino Xtra Condensed	Eng Gothic	Eng Gothic Ext
Eng Gothic Thin	Engaged	England
Engraved	Engraved Condensed	Engraved Thin
Enterprise	Enview	Enview Cond Light
Enview Light	Enview Thin	Enview Xtra Light
Epic	Epic Condensed	Epic Thin
Epic Wide	Eric	Eric Extended
Eric Lite	Eric Lite Extended	Eric Lite Thin
Eric Thin	Eric Wide	Ernest
Eurasia	Eurasia Condensed	Eurasia Extended
Eurasia Thin	Eurasia Wide	Evon
Executive	Exotica	Expel
Expel Extended	Expel Wide	Expose
Expose Condensed	Expose Thin	Expose Thin Cond
Expose Wide	Eye glass	Eye glass Condensed
Eye glass Extended	Eye glass Thin	Eye glass Wide
Fantasy	Fantasy Heavy	Fargo
Fatso	Fatso Condensed	Fatso Thin
Feline	Feline Condensed	Feline Extended
Feline Thin	Feline Wide	Financial
Finley	Flair	Flair Condensed
Flair Extended	Flair Thin	Flair Wide
Flat Brush	Flat Brush Cond	Flat Brush Ext
Flat Brush Thin	Flat Brush Wide	Fletch
Fletch Condensed	Fletch Extended	Fletch Thin
Fletch Wide	Flintstone	Flintstone Condensed
Flintstone Extended	Floral	Floral Condensed
Floral Wide	Fox	Francis High Light Cond
Francis High Lighted	Franciscan	Franco
Franco Condensed	Franco Extended	Franco Thin
Franco Wide	Frank	Fredric
Freedom	Freedom 9	Freedom 9 Cond
Freedom 9 Thin	Freedom 9 Wide	Freedom Condensed
Freedom Extended	Freedom Thin	Freedom Wide
Freehand	Freeze	Freeze D
Frisco	Frogger	Fuji
Fuji Condensed	Fuji Extended	Fuji Thin
Fuji Wide	Fusi	Fusi Condensed
Fusi Extended	Fusi Thin	Fusi Wide
Gaines	Galant	Galant Condensed
Galant Extended	Galant Thin	Galant Wide
Gallery	Gallery	Gallery Condensed
Gallery Wide	Garrick	Garrick Condensed
Garrick Extended	Garrick Thin	Garrick Wide
Gary	Gaston	Gaston Extended
Gaston Wide	Gaze	Gaze Condensed
Gene	Geneva	GenevaBlck
GenevaCmpr	GenevaCndn	GenevaLght
GenevaNrw	Geo	Geo 112
Geo 112 Condensed	Geo 112 Extended	Geo 112 Thin
Geo 112 Wide	Geo 579	Geo 579 Condensed
Geo 579 Extended	Geo 579 Thin	Geo 579 Wide

Table A.4 Font list 4 (alphabet)

Geo 957	Geo 957 Cond	Geo 957 Extended
Geo 957 Thin	Geo 957 Wide	Geo 986
Geo 986 Condensed	Geo 986 Extended	Geo 986 Thin
Geo 986 Wide	Geo Condensed	Geo Extended
Geo Thin	Geo Wide	Georgia
Gilbert	Gilliam 2	Givens
Gladys	Goducks	Goldish
Gooch	Gorgio	Gorgio Condensed
Gorgio Extended	Gorgio Wide	Gothic 32
Gothic 32 Condensed	Gothic 32 Extended	Gothic 32 Wide
Gothic 57	Gothic 57 Condensed	Gothic 57 Thin
Gothic 57 Wide	Granite	Greek
Greg	Gregory	Gregory Condensed
Gregory Thin	Gregory Wide	Gremlin Solid
Gretch	Grover	Gypsy
Hadley	Hadrian	Hak
Hall	Hank	Hanx
Hanzel	Hanzel Condensed	Hanzel Extended
Hanzel Thin	Hanzel Wide	Headline
Headline Cond	Headline Extended	Headline Thin
Headline Wide	Heather	HeraldRegular
Herin	Hex	Hinto
Hippo	Hobby	Hobby Condensed
Hobby Extended	Hobby Wide	Hodge
Holitas	Horn Condensed	Horn Extended
Horn Thin	Horn Wide	Hotch
Hughes	Hustle	Hustle Extended
Hustle Wide	Ian	Illini
Imperial	Indy	Indy 17
Indy 17 Extended	Indy 17 Wide	Indy Condensed
Indy Extended	Indy Thin	Indy Wide
Informal 2	Ira	Ironclad
Irv	Isaac	Jackie
James	Janet	Janis
Jantz	Jasmine	Java
Jdrfont	Jeff	Jerry
Jersey	Jessa	Jessica
Jester	Jimbo	Joan
Joel	John	Jolt
Jolt Extended	Jolt Wide	Jonson
Joseph	Jott 45	Journal
Julie	June	15-Jun
June 15 Extended	June 15 Wide	June Wide
Kadamol	Kaempf	Katzoff
Kedzie	Keira	Keira Condensed
Keira Extended	Keira Thin	Keira Wide
Kelly	Kelt	Kelt Condensed
Kelt Extended	Kelt Thin	Kelt Wide
Ken	Keyport	Keys
Keys Condensed	Keys Heavy	Kiev
Kindel	Kivetts	Kline
Kosher	Kosher Condensed	Kosher Extended
Kosher Thin	Kosher Wide	Kubis
Kyle	Lanny	Latina
Laura	Lauren	Lebanon
Lechter	Lechter Condensed	Lechter Extended
Lechter Thin	Lechter Wide	Lee
Legend	Lemond	Leo
Leo Condensed	Leo Extended	Leo Thin
Leo Wide	Leonard	Liberal
Liberate	Liberate Extended	Liberate Wide
Linda	Lindy	Lissa
Liste	Liste Condensed	Liste Extended
Liste Thin	Liste Wide	LittleHand
Lizard	LongIsland	Lookout
Loublue	Luciano	Luciano Condensed
Luciano Extended	Luciano Thin	Luciano Wide
Lumpy	Lux	Lynda
Lynda Condensed	Lynda Cursive	Lynda Extended
Lynda Thin	Lynda Wide	Lynne
Macedo	Mack	Majestic
Manuscript	Manuscript Cond	Manuscript Ext
Manuscript Thin	Manuscript Wide	Margret
Marka	Market	Marko
Marlin	Marlin Condensed	Marlin Thin
Marque	Marsett	Marsh
Martin	Mason Book	Mason Demi
Massey	Massey Condensed	Massey Extended
Massey Thin	Massey Wide	Maynard
Mechanical	Mellow	Melora
Memo	Memo Condensed	Metro
Michael	Mickey	Midevil
Midevil Extended	Midevil Wide	Mirage
Mirror	Mirror Condensed	Mirror Extended
Mirror Thin	Mirror Wide	Mkumba
Modern	ModernBlck	Mogenza
Momcat	Monogram	Mook
Mooner	Morgan	Mrsdog
Mystic	Mystic Condensed	Mystic Extended
Mystic Thin	Mystic Wide	Nadine
Nadine 2	Nadine 2 Condensed	Nadine 2 Extended

Table A.5 Font list 5 (alphabet)

Nadine 2 Thin	Nadine 2 Wide	Nadine Condensed
Nadine Extended	Nadine Thin	Nadine Wide
Nass	Neenah	Neil
Nelson	New Boston	New Boston Cond
New Boston Thin	New Boston Wide	New Eng. Engr. Condensed
New Eng. Engr. Wide	New England Engr	Niagara
Nicole	Ninepin	Nip
Norway	Norway Condensed	Norway Thin
Norway Wide	Notebook	Novelty Demi
Novelty Light	Oakland	Oconnor
Ohi	OldCenturyRegular	Olga
Opera	Optical A	Optical B
Optical C	Orinda	Orkand
Oyster	Oz	Page
Pageant	Palamino	Palamino Reverse
Pali	Paperclip	PaperPunch
Parade	Pare	Pare Cond Reverse
Pare Condensed	Pare Reverse	Pare Wide
Pare Wide Reverse	Partridge	Paul
Paulson	Peanut	Peejay
Pegasus	Pelota	Persia
Persia Condensed	Persia Extended	Persia Thin
Persia Wide	Peter	Pham
Phillip	Pickwick	Pierre
Pietro	Piikoi	Plano
Policy	Prestige	Price
Prodigal	Query	Quigley
Quill	Quirk	Rabin
Racetrac	Rai	Rally
Randy	Rapid	Rapid Extended
Rapid Thin	Rapid Wide	Reid
Rep	Reporter	Revive 8
Revive 8 Condensed	Revive 8 Extended	Revive 8 Thin
Revive 8 Wide	Richard	Riggs
Rockstone	Rocky	Roel
Roland	Ronnie	Roomy
Roomy Condensed	Roomy Extended	Roomy Thin
Roomy Wide	Rory	Rory Condensed
Rory Extended	Rory Thin	Rory Wide
Ross	Russell	Saddle
Saloon	Salsa	Samitch
Samurai	Sandra	Sceptre
Scott	Scottsdale	Scottsdale Condensed
Scottsdale Wide	Script	Script 33
Script 92	Scroll	Scroll Heavy
Seattle	Sedona	Sewell
Shadow	Sharon	Shell
Sher	Sherwood	Sheryl
Shipper	Short Hand	Short Hand Heavy
Showtime	Signboard	Simkins
Simpson	Simpson Cond Heavy	Simpson Condensed
Simpson Heavy	Sinbad	Slasher
Slasher Heavy	Slater	Sliver
Socket	Sojourn	Sonni
Sparky	Spear	Stars & Stripes
Steamer	Stencil	Stephen
Stevo	Stjohn	Stone
Storybook	Stubbs	Stucco
Stucco 27	Studio	Submarine
Subway	Sue	Surfer
Susanne	Sweden	Sweden Condensed
Sweden Extended	Swing	Tangiers
Tango	Tango Condensed	Tasha
Tech	Techno	Techno Heavy
Teletype	Template	Templett
Templett Condensed	Templett Extended	Templett S Cond
Templett Wide	Terfont	Teri
Terra	Terra Narrow	Tex
Textbook Demi	Textbook Light	Theatre
Thrashr	Time	Timothy
Toby	Tomas	Tomo
Topper	Transit	Transit 2
Transit 2 Cond	Transit 2 Wide	Transit Condensed
Transit Wide	Treasure	Tristan
Tubular	Twenty	Ulster
Umpque	Unicorn	Update 20
Update 20 Condensed	Update 537	Upperville
Upperville Condensed	Urara	Vagabond
Valhalla	Valhalla Condensed	Valhalla Wide
Valiant	Valley	Van
Vanduyn	Vanessa	Varnell
Varsity	Vaughn	Verona
Vestra	Vicki	Vienna
Villa	Vive	Viviene
Vizier	Vizier Condensed	Vizier Condensed Heavy
Vizier Heavy	Vockel	Vogel
Vogel Condensed	Vogel Wide	Vogue
Voltage	Voltage Thin	Vranish
Waddle	Walter	Warren
Webster	Wendle	William
Willow	Wolf	Wooster
Wrangler	Wundera	Yanzel
Zuerbig		

Table A.6 Font list 6 (katakana and hiragana)

AR P なごみＰＯＰ体 B	AR P ゴシック体 M	AR P ゴシック体 S	AR P ハイカラＰＯＰ体 H
AR P ペン楷書体 L	AR P ペン行楷書体 L	AR P ペン行楷書体 M	AR P マッチ体 B
AR P マーカー体 E	AR P 丸ゴシック体 3DM	AR P 丸ゴシック体 E	AR P 丸ゴシック体 M
AR P 丸印篆 B	AR P 丸印篆 L	AR P 勘亭流 H	AR P 古印体 B
AR P 宋朝体 M	AR P 悠々ゴシック体 E	AR P 教科書体 M	AR P 新藝体 E
AR P 新藝体 H	AR P 新藝体 U	AR P 明朝体 L	AR P 明朝体 U
AR P 板体 B	AR P 板体 E	AR P 板体 H	AR P 楷書体 M
AR P 浪漫明朝体 U	AR P 版画ＰＯＰ体 E	AR P 白丸ＰＯＰ体 H	AR P 祥南真筆行書体 M
AR P 竹管ＰＯＰ体 B	AR P 花文字梅 U	AR P 行書体 B	AR P 行書体 M
AR P 行楷書体 H	AR P 行楷書体 L	AR P 隷書体 M	AR P 顔眞楷書体 H
AR P 髭勘亭 H	AR P 黒丸ＰＯＰ体 H	AR P ＰＯＰ体 B	AR P ＰＯＰ４ B
AR P ＰＯＰ５ H	AR なごみＰＯＰ体 B	AR ゴシック体 M	AR ゴシック体 S
AR ハイカラＰＯＰ体 H	AR ペン楷書体 L	AR ペン行楷書体 L	AR ペン行楷書体 M
AR マッチ体 B	AR マーカー体 E	AR 丸ゴシック体 3DM	AR 丸ゴシック体 E
AR 丸ゴシック体 M	AR 丸印篆 B	AR 丸印篆 L	AR 勘亭流 H
AR 古印体 B	AR 宋朝体 M	AR 悠々ゴシック体 E	AR 教科書体 M
AR 新藝体 E	AR 新藝体 H	AR 新藝体 U	AR 明朝体 L
AR 明朝体 U	AR 板体 B	AR 板体 E	AR 板体 H
AR 楷書体 M	AR 浪漫明朝体 U	AR 版画ＰＯＰ体 E	AR 白丸ＰＯＰ体 H
AR 祥南真筆行書体 M	AR 竹管ＰＯＰ体 B	AR 花文字梅 U	AR 行書体 B
AR 行書体 M	AR 行楷書体 H	AR 行楷書体 L	AR 隷書体 M
AR 顔眞楷書体 H	AR 髭勘亭 H	AR 黒丸ＰＯＰ体 H	AR ＰＯＰ体 B
AR ＰＯＰ４ B	AR ＰＯＰ５ H	BT 10G Dot Bold	BT 10G Dot Light
BT 10G Dot Regular	BT 10G Inline-T Regular	BT 10G Inline-T Round	BT 10G Inline-Y Regular
BT 10G Inline-Y Round	BT 10G LCD Bold	BT 10G LCD Light	BT 10G LCD Regular
BT 10G Smooth Regular	BT 10G Star Regular	BT 10G Stitch Regular	C4 キセノン E
C4 キセノン H	C4 クリプトン E	C4 クリプトン H	C4 ゴシック・ドゥ Nexus D
C4 ゴシック・ドゥ Nexus E	C4 ゴシック・ドゥ Nexus L	C4 ゴシック・ドゥ Nexus M	C4 ゴシック・ドゥ Nexus R
C4 サマリウム E	C4 サマリウム H	C4 スクエア D	C4 スクエア M
C4 セリウム E	C4 セレン E	C4 セレン H	C4 タンタル E
C4 タンタル H	C4 テルル E	C4 ニューズ Nexus L	C4 ニューズ Nexus R
C4 ネオジム E	C4 ネオジム H	C4 ビオゴ Nexus D	C4 ビオゴ Nexus E
C4 ビオゴ Nexus H	C4 ビオゴ Nexus L	C4 ビオゴ Nexus M	C4 ビオゴ Nexus R
C4 ビスマス E	C4 ビスマス H	C4 ポロニウム E	C4 ミンニアム Nexus E
C4 ミンニアム Nexus M	C4 ミンニアム Nexus R	C4 ユニバーサルビュー BDY D	C4 ユニバーサルビュー BDY EL
C4 ユニバーサルビュー BDY R	C4 ユニバーサルビュー DSP D	C4 ユニバーサルビュー DSP E	C4 ユニバーサルビュー DSP EL
C4 ユニバーサルビュー DSP R	C4 ユニバーサルライン BDY D	C4 ユニバーサルライン BDY L	C4 ユニバーサルライン BDY R
C4 ユニバーサルライン DSP D	C4 ユニバーサルライン DSP E	C4 ユニバーサルライン DSP L	C4 ユニバーサルライン DSP R
C4 ユニバーサルライン LG E	C4 ランタン E	C4 レニウム E	C4 レニウム H
GD-高速道路ゴシック JA-TTF	GKSP 楷書 M	GMAP ひげ文字 U	GMAP 俵 H
GMAP 古印体 EB	GMAP 相撲文字 H	GMAP 行書 B	GMYP インラインゴシック U
GMYP インライン丸ゴシック U	GMYP ゴシック ORU	GMYP メタルゴシック B	GMYP 丸ゴシック ORU
GMYP 丸シャドー DB	GMYP 丸シャドー OREB	GSNP ひげ文字 EB	GSNP プリティフランク B
GSNP プリティフランク H	GSNP プリティフランク HL	GSNP プリティフランク HS	GSNP 勘亭流 EB
GSNP 演芸 B	GSNP 演芸 EB	GSNP 行書 B	GSNP 行書 M
GSNP 隷書 DB	GSNP 隷書 M	GTUP 楷書 M	HGP 創英角 UB
HGP 創英角体	HGP 創英 EB	HGP 教科書体	HGP 明朝 B
HGP 明朝 E	HGP 行書体	HGPE	HGPM
HGS 創英角 UB	HGS 創英角体	HGS 創英 EB	HGS 教科書体
HGS 明朝 B	HGS 明朝 E	HGS 行書体	HGSE
HGSM	HG 丸 M-PRO	HG 創英角 UB	HG 創英角体
HG 創英 EB	HG 教科書体	HG 明朝 B	HG 明朝 E
HG 正楷書体-PRO	HG 行書体	HGE	HGM
Meiryo UI	MS UI Gothic	MT たれ	NSK P 白洲ペン楷書
NSK P 白洲ペン楷書太	NSK P 白洲ペン楷書極太	NSK P 白洲ペン行草	NSK P 白洲ペン行草太
NSK P 白洲ペン行草極太	NSK P 白洲毛筆宛名楷書	NSK P 白洲毛筆楷書	NSK P 白洲毛筆楷書太
NSK P 白洲毛筆楷書極太 EG	NSK P 白洲毛筆行草	NSK P 白洲毛筆行草太	S2G うにフォント
S2G うみフォント	S2G つきフォント	S2G メモ	S2G 月フォント
S2G 殴り書き	あくびん	あずきフォント	あやせ
あんずもじ	あんずもじ始	あんずもじ湛	うずらフォント
えるまー P	おひさまフォント	かるた-Bold	かるた-Regu
かるた-Thin	かるた丸-Medium	かんなな	くれよん
こころフォント	しねきゃぷしょん	たえふぉん	たぬき油性マジック
たまうすもじ	とねり	にくきゅう	はなはた
ふい字	ぷちはんど　ほそぺん	ほにゃ字	まきばフォント
まるっこ	みかちゃん	もじゃ字	りりふぉんと
アームドバナナ	アームドレモン	イバラ字	メイリオ
モフ字	ラヴポップ	九ちゃんフォント	五風十雨
和楽-Bold	和楽-Light	和楽-Medium	和楽丸-Medium
喜楽-Bold	喜楽-Heavy	喜楽-Light	喜楽-Medium
喜楽-Ultra	大和楷書	大和篆書	怨霊
梅 P ゴシック	梅 P ゴシック C4	梅 P ゴシック C5	梅 P ゴシック O5
梅 P ゴシック S4	梅 P ゴシック S5	梅 P 明朝	梅 P 明朝 S3
梅 UI ゴシック	梅 UI ゴシック O5	梅ゴシック	梅ゴシック C4
梅ゴシック C5	梅ゴシック O5	梅ゴシック S4	梅ゴシック S5
梅明朝	梅明朝 S3	水面字	疾風
白舟印相体教漢	白舟古印体教漢	白舟極太楷書教漢	白舟楷書教漢
白舟篆古印教漢	白舟篆書教漢	白舟草書教漢	白舟行書 Pro 教漢
白舟行書教漢	白舟隷書教漢	衡山毛筆フォント	衡山毛筆フォント草書
衡山毛筆フォント行書	雅楽-Bold	雅楽-Light	雅楽-Medium
雅楽丸-Medium	青柳疎石フォント 2	青柳衡山フォント T	青柳隷書しも
飛燕	駿河-Bold	駿河-Heavy	駿河-Light
駿河-Medium	駿河-Ultra	駿河丸-Medium	Ｃ＆Ｇ P れいしっく
Ｃ＆Ｇ P ブーケ	Ｃ＆Ｇ P 半古印	Ｃ＆Ｇ P 行刻	Ｃ＆Ｇれいしっく
Ｃ＆Ｇブーケ	Ｃ＆Ｇ半古印	Ｃ＆Ｇ行刻	ＤＦ POP1 体
ＤＦまるもじ体 W7	ＤＦまるもじ体 W9	ＤＦ中楷書体	ＤＦ勘亭流
ＤＦ唐風隷書体 W5	ＤＦ唐風隷書体 W9	ＤＦ平成明朝体 W3	ＤＦ平成明朝体 W5
ＤＦ平成明朝体 W7	ＤＦ平成明朝体 W9	ＤＦ康印体 W4	ＤＦ新宋体
ＤＦ極太ゴシック体	ＤＦ極太明朝体	ＤＦ極太楷書体	ＤＦ流隷体 W7
ＤＦ痩金体 W3	ＤＦ相撲体 W12	ＤＦ祥南行書体 W5	ＤＦ綜藝体 W9
ＤＦ行書体	ＤＦ魏碑体 W7	ＤＦ麗雅宋	ＭＳ ゴシック
ＭＳ 明朝	ＭＳ Ｐゴシック	ＭＳ Ｐ明朝	ＲＦゴシック-Ｅ
ＲＦナウ-ＭＢ	ＲＦ羽衣-Ｍ		

Table A.7 Font list 7 (kanji)

AR 板体 E	BT 10G Dot Bold	BT 10G Dot Light
BT 10G Dot Regular	BT 10G Inline-T Regular	BT 10G Inline-T Round
BT 10G Inline-Y Regular	BT 10G Inline-Y Round	BT 10G LCD Bold
BT 10G LCD Light	BT 10G LCD Regular	BT 10G Smooth Regular
BT 10G Star Regular	BT 10G Stitch Regular	C4 キセノン E
C4 キセノン H	C4 クリプトン E	C4 クリプトン H
C4 ゴシック・ドゥ Nexus D	C4 ゴシック・ドゥ Nexus E	C4 ゴシック・ドゥ Nexus L
C4 ゴシック・ドゥ Nexus M	C4 ゴシック・ドゥ Nexus R	C4 サマリウム E
C4 サマリウム H	C4 スクエア D	C4 スクエア M
C4 セリウム E	C4 セレン E	C4 セレン H
C4 タンタル E	C4 タンタル H	C4 テルル E
C4 ニューズ Nexus L	C4 ニューズ Nexus R	C4 ネオジム E
C4 ネオジム H	C4 ビオゴ Nexus D	C4 ビオゴ Nexus E
C4 ビオゴ Nexus H	C4 ビオゴ Nexus L	C4 ビオゴ Nexus M
C4 ビオゴ Nexus R	C4 ビスマス E	C4 ビスマス H
C4 ポロニウム E	C4 ミンニアム Nexus E	C4 ミンニアム Nexus M
C4 ミンニアム Nexus R	C4 ユニバーサルビュー BDY D	C4 ユニバーサルビュー BDY EL
C4 ユニバーサルビュー BDY R	C4 ユニバーサルビュー DSP D	C4 ユニバーサルビュー DSP E
C4 ユニバーサルビュー DSP EL	C4 ユニバーサルビュー DSP R	C4 ユニバーサルライン BDY D
C4 ユニバーサルライン BDY L	C4 ユニバーサルライン BDY R	C4 ユニバーサルライン DSP D
C4 ユニバーサルライン DSP E	C4 ユニバーサルライン DSP L	C4 ユニバーサルライン DSP R
C4 ユニバーサルライン LG E	C4 ランタン E	C4 レニウム E
C4 レニウム H	GD-高速道路ゴシック JA-TTF	GMAP ひげ文字 U
GMAP 俵 H	GMAP 古印体 EB	GMAP 相撲文字 H
GMAP 行書 B	GMYP インラインゴシック U	GMYP インライン丸ゴシック U
GMYP ゴシック ORU	GMYP メタルゴシック B	GMYP 丸ゴシック ORU
GMYP 丸シャドー DB	GMYP 丸シャドー OREB	GSNP ひげ文字 EB
GSNP プリティフランク B	GSNP プリティフランク H	GSNP プリティフランク HL
GSNP プリティフランク HS	GSNP 勘亭流 EB	GSNP 演芸 B
GSNP 演芸 EB	GSNP 行書 B	GSNP 行書 M
GSNP 隷書 DB	GSNP 隷書 M	GTUP 楷書 M
HGP 創英角 UB	HGP 創英角体	HGP 創英 EB
HGP 教科書体	HGP 明朝 B	HGP 明朝 E
HGP 行書体	HGPE	HGPM
HGS 創英角 UB	HGS 創英角体	HGS 創英 EB
HGS 教科書体	HGS 明朝 B	HGS 明朝 E
HGS 行書体	HGSE	HGSM
HG 丸 M-PRO	HG 創英角 UB	HG 創英角体
HG 創英 EB	HG 教科書体	HG 明朝 B
HG 明朝 E	HG 正楷書体-PRO	HG 行書体
HGE	HGM	Meiryo UI
MS UI Gothic	MT たれ	NSK P 白洲ペン楷書
NSK P 白洲ペン楷書太	NSK P 白洲ペン楷書極太	NSK P 白洲ペン行草
NSK P 白洲ペン行草太	NSK P 白洲ペン行草極太	NSK P 白洲毛筆宛名楷書
NSK P 白洲毛筆楷書	NSK P 白洲毛筆楷書太	NSK P 白洲毛筆楷書極太 EG
NSK P 白洲毛筆行草	NSK P 白洲毛筆行草太	Oakland
Oconnor	Ohi	S2G うにフォント
S2G つきフォント	S2G メモ	S2G 月フォント
S2G 殴り書き	あくびん	あずきフォント
あんずもじ	あんずもじ始	あんずもじ湛
うずらフォント	えるまー P	おひさまフォント
かるた-Bold	かるた-Regu	かるた-Thin
かるた丸-Medium	しねきゃぷしょん	じゃぽねすく
たまうすもじ	ふい字	ほにゃ字
まきばフォント	みかちゃん	アームドバナナ
アームドレモン	メイリオ	モフ字
九ちゃんフォント	五風十雨	和楽-Bold
和楽-Light	和楽-Medium	和楽丸-Medium
喜楽-Bold	喜楽-Heavy	喜楽-Light
喜楽-Medium	喜楽-Ultra	大和楷書
大和篆書	怨霊	梅 P ゴシック
梅 P ゴシック C4	梅 P ゴシック C5	梅 P ゴシック O5
梅 P ゴシック S4	梅 P ゴシック S5	梅 P 明朝
梅 P 明朝 S3	梅 UI ゴシック	梅 UI ゴシック O5
梅ゴシック	梅ゴシック C4	梅ゴシック C5
梅ゴシック O5	梅ゴシック S4	梅ゴシック S5
梅明朝	梅明朝 S3	水面字
疾風	衡山毛筆フォント	衡山毛筆フォント草書
衡山毛筆フォント行書	雅楽-Bold	雅楽-Light
雅楽-Medium	雅楽丸-Medium	青柳疎石フォント 2
青柳衡山フォント T	青柳隷書しも	飛燕
駿河-Bold	駿河-Heavy	駿河-Light
駿河-Medium	駿河-Ultra	駿河丸-Medium
ＤＦ POP1 体	ＤＦまるもじ体 W7	ＤＦまるもじ体 W9
ＤＦ中楷書体	ＤＦ勘亭流	ＤＦ唐風隷書体 W5
ＤＦ唐風隷書体 W9	ＤＦ平成明朝体 W3	ＤＦ平成明朝体 W5
ＤＦ平成明朝体 W7	ＤＦ平成明朝体 W9	ＤＦ康印体 W4
ＤＦ新宋体	ＤＦ極太ゴシック体	ＤＦ極太明朝体
ＤＦ極太楷書体	ＤＦ流隷体 W7	ＤＦ痩金体 W3
ＤＦ相撲体 W12	ＤＦ祥南行書体 W5	ＤＦ綜藝体 W9
ＤＦ行書体	ＤＦ魏碑体 W7	ＤＦ麗雅宋
ＭＳ ゴシック	ＭＳ 明朝	ＭＳ Ｐゴシック
ＭＳ Ｐ明朝	ＲＦゴシック-Ｅ	ＲＦナウ-ＭＢ
ＲＦ羽衣-Ｍ		

B

Supplementary information: grid layout generation method

B.1 Images of the experiment for grid layout generation method

All images of the experiment is shown in Figure B.1 and Figure B.2.

Fig. B.1 15 images (portrait)

Fig. B.2 15 images (landscape)

C

Supplementary information: color scheme search method

C.1 Images of the experiment for color scheme search

All images of the experiment are shown in Figure C.1.

Fig. C.1 10 vector images