Cross-cultural Image Database System with Impression-based Color Arrangement

Shiori Sasaki[1], Yoshiko Itabashi[2], Diep Thi-Ngoc Nguyen[2], Yasushi Kiyoki[3],
Ali Ridho Barakbah[4] and Kosuke Takano[5]
[1] School of Media and Governance, Keio University, Japan
[2] Keio Research Institute at SFC, Japan
[3] Faculty of Environmental Information, Keio University, Japan
[4] Electronic Engineering Polytechnic Institute of Surabaya EEPIS, Indonesia
[5] Kanagawa Institute of Technology, Japan
Email: {[1]sashiori, [3]kiyoki}@sfc.keio.ac.jp, [2]ngocdiep@vnu.edu.vn,
[4]ridho@eepis-its.edu, [5]takano@ic.kanagawa-it.ac.jp

Abstract

Colors and color combinations are tightly associated with human impressions for image data, and color-oriented impression varies between cultures. Though the shape and structure of images are important feature for retrieving similar images in the field of Content-based Image Retrieval (CBIR), in this paper, we focus on color feature of images because the purpose of our research is to create a cross-cultural and dynamic media designing environment using culture-dependent color-impressions for cultural property's images, especially, images of patterns used in cultural products. The main feature of our cross-cultural image database system for cultural-product design is characterized as the following three functions: (1) Impression-based color arrangement, (2) Culture-based color-space transformation among culture-dependent color collections, and (3) Attribute-based data selection and mapping. First, in our system, a set of images of patterns are colored by impression-based color combinations. Second, the set of colors in images are transformed by culture-dependent color collections. Third, the target images are selected sharply by the attribute of images such as country, region, village, tribe, author, designer, weaver, e.t.c. and mapped onto the multi-dimensional view. The most important contribution of our research is that our system creates linkage among different cultures by sharing and arranging multimedia information by collaborative work. The applications hold enormous potential for promoting regional economic development or innovative tourist business by cooperative designing of cultural products and new industries targeting global markets with remote collaborators in different cultural background.

Keywords: Cultural Computing, Media Design, Image Processing, Color Information, Human Computer Interface

1. Introduction

Cultural computing is an emerging field of multidisciplinary computer science [1][2][3]. Though the subject of this field covers wide domains, the common objective of researches is to promote communication and understanding within and between diverse communities and foster creative activities and opportunities [2]. In the near future, cultural computing will contribute to several important applications in the fields of software engineering, business, art, the humanities, the social science, education, health care, and environmental issues.

As well as cultural computing, "cross-cultural computing", which is focus on the collaborative research and communication, deep analysis on subtle cultural differences, knowledge creation and sharing using multimedia data, is also becoming one of the important research areas [11]-[20]. *Impression-based Multimedia Retrieval Method* [4][5][6][7], *Cross-cultural Collaborative System* [12][13][14][15], *Image-Query Creation Method* using historical/cultural properties[11], *Cross-cultural Image Computing* [16], *Cross-cultural Music Environments* [17][18], *Culture-dependent Metadata Creation Method by Cultural Color Spaces* [19], *Term-based Cross-Cultural Computing System* [20] have been proposed in these years.

The base of these researches can be summarized by an assumption that the most essential point to communicate among diverse communities and foster creative activities is finding "common features" of each cultural background, and finding "subtle differences" among cultural properties.

Based on these backgrounds, we propose a cross-cultural image database system with impression-based color arrangement functions for images of patterns by reflecting subtle differences of color expressions among cultures. The purpose of our research is to create a cross-cultural and dynamic media designing environment using culture-dependent impressions with color of cultural property's images, especially, images of patterns which are used in cultural products. The most important contribution of our system is to create linkage among different cultures by sharing the multimedia information. The applications hold enormous potential for promoting regional economic development or innovative tourist business by cooperative designing of cultural products and new industries targeting global markets with remote collaborators in different cultural background. Especially, our system supports cooperative designing of cultural products from color aspects. By our system, users can design the color arrangement of cultural

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products by reflecting the knowledge of culture-dependent colors to them. For example, by using our system, designers of cultural products in each country can arrange the colors of their products according to the customers' cultural backgrounds. By a Web-based application of our system for e-commerce, customers of cultural products around the world can create their own color arrangements based on their cultural background or personal preferences and order them through Internet.

Colors and color combinations are tightly associated with human impressions for image data, and color-oriented impressions vary between cultures. The degree of color variety differs between cultures, and each color name is designated uniquely in a language. In content-based image processing, color is the most important feature, and researchers have studied color content-based image retrieval extensively. Thus, in this paper, we focus on color feature of images because the purpose of our research is to create a cross-cultural and dynamic media designing environment, though the shape and structure of images are important feature for retrieving similar images in the field of content-based image processing.

The main feature of our cross-cultural image database system for cultural-product design is characterized as three functions: (1) Impression-based color arrangement, (2) Culture-based color-space transformation among culture-dependent color collection, and (3) Attribute-based data selection and mapping. First, in our system, a set of images of patterns are arranged by impression-based color combinations. Second, the set of colors in images are transformed by culture-dependent color collections. Third, the target images are selected sharply by the attribute of images such as country, region, village, tribe, author, designer, maker, weaver, e.t.c. and mapped onto the multi-dimensional view.

2. Basic Method of Impression-based Color Arrangement with Culture-dependent Color Collections

The main feature of our cross-cultural image database system for cultural-product design is characterized as three functions: (1) Impression-based color arrangement, (2) Culture-based color-space transformation among culture-dependent color collection, and (3) Attribute-based data selection and mapping.

We assume that "culture" in image data, especially in textile design, is represented by style of patterns and color combinations. Thus, we create our cross-cultural image database system by the following data sets: (a) impression-based color combination schemas, (b) culture-dependent color collections, and (c) culture-dependent pattern collections. The relations between three functions (1)(2)(3) and data sets (a)(b)(c) are represented in Figure 1.

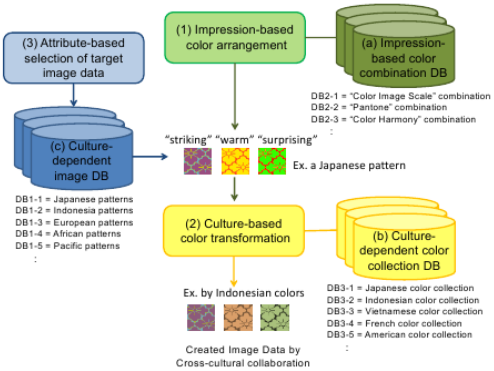

Figure 1 System architecture and data sets in our cross-cultural image database with impression-based color arrangement

The process of our system is described by 3 steps.

Step 1: Attribute-based selections of target image data
Culture-dependent patterns are collected by each culture, such as Japanese traditional patterns, European modern patterns, African traditional patterns, and so on, and stored as a database of (c) culture-dependent color collections, in advance. By keyword-based pattern matching, target image data for color arrangement is selected according to user's input.

Step 2: Impression-based color arrangement
A set of images of patterns selected by Step 1 is arranged by impression-based color combinations. Impression-based color combinations are collected by each culture or age based on research results of color science, color psychology and historical study of color [23]-[31], such as "Color Image Scale (CIS) [24]" combinations, "Pantone [25][26][27]" color combinations, "Color Harmony [28]" combinations and so on, and stored as a database of (a) impression-based color combinations, in advance. By keyword-based pattern matching, a set of impression-based color combinations is selected according to user's input.

Step 3 Culture-based color-space transformation among culture-dependent color collections
A set of colors of images arranged by Step 2 is transformed by culture-dependent based color collections. Culture-dependent color collections are collected by each culture or age, such as Japanese traditional color collections, Indonesian color collections for interior design, Vietnamese traditional color collections and so on, and stored as a database of (b) culture-dependent color collections, in advance. By keyword-based pattern matching, a set of culture-dependent color collections is selected according to user's input.

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By this final process, the color arrangement for patterns becomes more natural and accurately-matched design for cultural products.

2.1 Impression-based color arrangement

By using research results of color science, color psychology and historical study of color [23]-[31], the relationships between a set of colors and impressions are represented by a color-impression matrix. For r impression words (e_1, e_2, …, e_r), each word is characterized by m basic colors (c_1, c_2, …, c_m). The r impression words are given in the form of an r by m matrix M.

By creating matrix M by each research result of color science, color psychology and historical study, the knowledge about color combinations and impressions by culture, region, and age are represented by M_1, M_2, …, M_s. These color-impression matrices are stored in an impression-based color combination database and utilized to color arrangement for target image by conversion of original color information of each pixel of the target image data to transformed color information of a corresponding pixel.

Here, a color combination of an impression word of M_k consisting of l colors is represented as ($c_{Mk\text{-}1}$, $c_{Mk\text{-}2}$, …, $c_{Mk\text{-}l}$).

If the number of pixels of a target image data is represented as p x q, the position of a pixel is represented as (x_i, y_j), a color of each pixel is represented as c_{ij}, and an original color of a pixel of a target image is represented as $c_{o\text{-}i}$, a function $f_{convert}$ to convert the original color to an impression-based combination in M_k is represented as below.

$$f_{convert}((c_{o\text{-}1}, x_1, y_1), (c_{o\text{-}2}, x_1, y_2), \ldots, (c_{o\text{-}m}, x_p, y_q)) \rightarrow ((c_{Mk\text{-}1}, x_1, y_1), (c_{Mk\text{-}2}, x_2, y_2), \ldots, (c_{Mk\text{-}l}, x_p, y_q)) \quad (1)$$

2.2 Multiple color-space transformation among culture-dependent color collection

The objective of constructing this function is to refrect knowledge on cultural background of each culture-dependent color collections to color arrangement for pattern images and support user's intension for design on cultural/geographical/historical differences by using color information of image data. We define color appearance system and a set of color names as culture-dependent color collections.

Color systems can be categorized to two main types: (1) color mixing system (e.g. RGB, XYZ, e.t.c.) and (2) color appearance system (e.g. Munsell Color System, PCCS, DIC, NCS, e.t.c.). Whereas color mixing system is a system of colors made by psycho-physical chromatic stimuli, color appearance system is a system of colors which are recognizable to human being. The color elements in color appearance system are represented as color chart or systematic code.

Generally, for color quantization of image processing, color space (e.g. RGB, XYZ, HSV, HLS, CIELAB, CIELUV, CIEXYZ, e.t.c.), which is derived from color mixing system, is used. Whereas CIELAB and CIELUV are derived from XYZ and used as uniform color space, HSV and HLS are derived from RGB and adapted to human recognition.

However, for communication among ordinary people, it is not popular to use numerical value on color space but color name. Though systemic color names based on color appearance system are used to represent exact color information in the field of media design, it is more popular to use the name of specific colors in daily life for people other than specialists of design and art. Thus, we propose a method to transform a color in color system to that in culture-dependent color collections for cross-cultural communication using color names.

Color names are a set of semantics and words based on cultural background and used in a different dimension than in color system and color space. Color names can be categorized as three main types: basic color names, systemic color names and other color name collections. Basic color names are recognized by humans as word universally [33], though the range of color names is different by culture, country and age. Systemic color names have been defined as standardized system for practical use such as ISCC-NBS and JIS. Other color name collections including local color names and traditional color names have been used by people in specific area/culture. Local color names and traditional color names represent the derivation and origin. These color names can be considered as representation of the differences in cultural background, geographical features and climate of area and people's sense of color. Thus, we define these color name collections as culture-dependent color collections in this research.

Based on the studies of color science [23]-[31], cognitive psychology [33], ethno biology [34], cultural and linguistic anthropology, we assume that a set of culture-based colors represents a kind of discrimination capability of each culture to recognize the color information of an image. That is, a set of traditional colors discriminates the subtle difference between two primitive colors in a range of view and an image.

From a technical aspect, it is difficult to treat uneven distributions of different color collections and color names. Thus, we focus on a method to treat these color name collections, especially culture-dependent color collections by color space transformations. To treat the heterogeneous distribution of colors in culture-dependent color collections appropriately, we apply Similarity Matrix used in Quadratic Form Distance (QFD) [35][36] and Weighted Correlation (WC) [37], which are methods to compare color histograms made by different scales.

There are several methods to calculate the distance between color histograms such as Earth Movers Distance (EMD) [38], QFD and WC [37]. In this case, we apply Similarity Matrix of QFD and WC to

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calculate the distance between color histograms in different color systems.

In these matrices, if an color element vector of *n*-dimensional color system (e.g. RGB) is defined as C = (c_1, c_2, …, c_n) and a vector of *m*-dimensional color sets (e.g. Japanese traditional colors) as C' = (c'_1, c'_2, …, c'_m), the similarity a_{ij} between color *i* in a *n*-dimensional color system and color *j* in a *m*-dimensional color sets is represented as follows.

$$\begin{aligned}&\text{Color Set } C: c_1, c_2, \ldots, c_n\\&\text{Color Set } C': c'_1, c'_2, \ldots, c'_m\\&\text{Similarity Matrix } \mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & & \vdots \\ \vdots & & \ddots & \vdots \\ a_{m1} & \cdots & \cdots & a_{mn} \end{bmatrix}\\&a_{ij} = w(d(c_i, c'_j)) : \text{color similarity function} (0 \le a_{ij} \le 1)\\&d(c_i, c'_j) : \text{distance between color } c_i \text{ and color } c_j\end{aligned} \quad (2)$$

Each element of color set C corresponds to its centroid of the histogram.

Similarity value a_{ij} in Similarity Matrices {A_1, A_2, …, A_{IC2}} in our method are calculated in the same way of QFD [20] as follows.

$$a_{ij} = \exp(-\sigma(d_{ij} / d_{\max})) \quad (3)$$

d_{ij} : distance between color *i* in a *n*-dimensional color system and color *j* in a *m*-dimensional color sets for mapping

σ = constant

d_{ij} is calculated by an exponent function to make position black color in relation to white color as a pure color relates to the opponent color in HSV cylinder model . This calculation reduces the deviation for monochrome colors.

σ is determined by a threshold of distance between any color and white color in HSV color space . The threshold is determined according to the dimension of a selected color sets for mapping.

3. Implementation

We implemented a prototype system to examine the feasibility of our method. In our system, various color sets are used for knowledge description and reference color sets. Thus, we implemented 2D visualization of reference color sets and culture-dependent color collections.

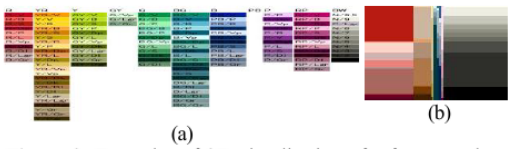

Figure 2. Examples of 2D visualization of reference color sets and color histograms: (a) the visualized color distribution feature of reference-color sets (CIS):: horizontal axis represents hue and vertical axis represents saturation and value, and (b) color-histogram of each image or impression word is represented as a rectangle with color area ratios.

In the 2D visualization shown in Figure 2, horizontal lines represent hue, and vertical lines represent saturation and value. In the horizontal lines, the hue values, in groups of 11, are allocated from red colors at the left to achromatic colors at right. In the vertical lines, the Saturation and Value values are allocated from vivid colors at the top to dark colors at bottom.

Table 1 shows examples of culture-dependent color collections by 2D visualization in the implemented system.

Table 1. 2D visualization of culture-dependent color collections and systematic color models

Chinese 320	Japanese 300	French 322	Indonesian 106
Vietnamese 132	PCCS	R6:G6:B6 / 216 colors	H12:S4:V4 / 192 colors

We have collected 320 from Chinese, 300 from Japanese, 322 from French, 106 from Indonesian and

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132 from Vietnamese colors for the traditional color sets. The DIC Color Guide [29] defines the Chinese, Japanese and French traditional colors, and native color specialists collected the Indonesian and Vietnamese traditional colors.

Based on this visualization, the characteristics of each traditional/reference color set can be grasped at a big-picture perspective. For example, one characteristic of the Japanese traditional color collection is including more yellow/orange/brown colors than other color sets. The Japanese traditional color collection thus has a high discriminative ability for yellow/orange/brown colors. In this sense, the Indonesian traditional color set has a high ability to discriminate green and purple colors, whereas the Chinese traditional color collection can discriminate between monochrome colors. The Indonesian and Vietnamese traditional color collections contain vivid colors, colors with high values in saturation and value, which may be due to geographical reasons, including climate. Conversely, the structure of Vietnamese colors is similar to that of French colors, which is considered as a historical influence from the French to Vietnamese cultures.

For reference and comparison, the lower columns of Table 1 show examples of visualizing color partitioning in RGB and HSV. R6:G6:B6 means a color set generated by segmenting RGB into 6 parts for each axis, and H12:S4:V4 means a color set generated by segmenting HSV into 12 parts for H, 4 parts for S and 4 parts for V.

PCCS [30] can be categorized as a set of systemic color names, as can Color Image Scale (CIS) and the color chart created by the Japanese Color Research Center [24].

4. Experiments

In this section, we present several examples of impression-based color arrangement for culture-dependent pattern data to examine the applicability of our system by using our prototype system described in section 3.

We set the following data sets for impression-based color combination schemas, culture-dependent color collections and culture-dependent pattern image collections based on the system architecture described in section 2.

(a) Impression-based color combination schemas

- Color Image Scale (CIS) 1 [24]: 250 kinds of impression-based color schemas constructed by 3 tone colors using 130 basic colors
- Color Image Scale (CIS) 2 [24]: 180 kinds of impression-based color schemas:: aggregated color combination of 180 impressions using 130 basic colors
- Art of Color Combination (Color Image Work) [31]: 50 kinds of impression-based color schemas constructed by 5 tone colors using 61 basic colors (DIC and CMYK)
- Pantone [25] [26][27]: 521 kinds of impression-based color schemas
- Color Harmony [28]: 324 kinds of impression-based color schemas:: 9 impressions x 36 color combinations

(b) Culture-dependent color collections

- Chinese Traditional Color Collection [29]: 320 colors
- Japanese Traditional Color Collection: 300 colors
- French Traditional Color Collection [29]: 322 colors
- Italian Traditional Color Collection: 211 colors
- Russian (Ukraine) Traditional Color Collection: 206 colors
- Indonesian Color Collection for Interior Design: 106 colors
- Vietnamese Traditional Color Collection: 132 colors
- American Traditional Color Collection: 178 colors
- European Traditional Color Collection: 206 colors
- Korean Traditional Colors: 53 colors
- Ancient Egyptian Colors: 19 colors

(c) Culture-dependent pattern collections.

- World Design Patterns [32]: 284 traditional patterns from Japan, Asia, Africa, Europe, and Pacific/Oceania regions.
- Originally-collected & digitized pattern data for textile design in the world: 232 traditional patterns of textile from Japan, Thai, China, Vietnam, England, France, Germany, Italy, French and Canada.

In Figure 3, examples of collected culture-dependent pattern images selected from World Design Patterns collection [32] are shown in Figure 3. The collection includes patterns which consist of 2 tone colors, 3 tone colors and 4 tone colors. The number of colors in each image is important for color arrangement because the allocation and area ratio of dominant color, accent color and subordinate colors based on the combination of “same”, “similar”, “contrasting”, “complementary” and “achromatic” colors in product design.

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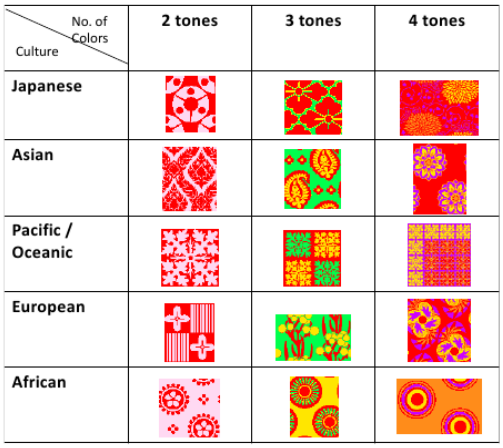

Figure 3. Examples of collected culture-dependent pattern images consisting of 2 tone colors, 3 tone colors and 4 tone colors selected from [32].

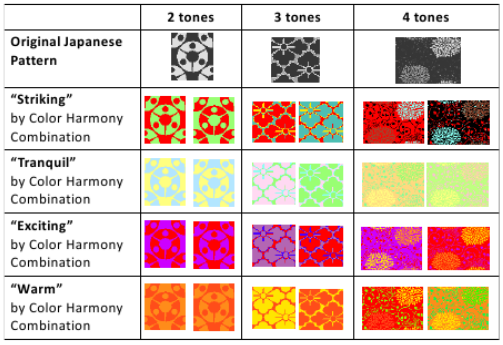

Figure 4. Examples of results of impression-based color arrangement by our system: 3 examples of Japanese patterns [32] are colored by impression-based color schemas of "striking", "tranquil", "exciting", and "warm" from Color Harmony color combinations [28].

In Figure 4, examples of results of impression-based color arrangement by our system. 3 examples of Japanese patterns selected from [32] are colored by impression-based color schemas of "striking", "tranquil", "exciting", and "warm" from Color Harmony color combinations [28]. The most simple examples are shown by 2-tones patterns. For example, "striking" color combinations are represented by color arrangement of red and yellow-green colors and inverted allocation. In the same way, "striking" color-impression is represented by red and light-blue dominant colors with yellow accent color in a 3-tone pattern, and by red and black dominant colors with light-blue accent color and blown subordinate colors.

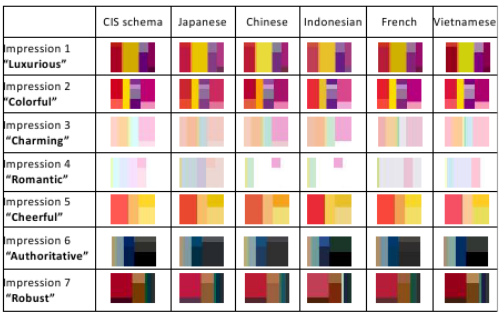

Figure 5. Redisplay of impression-based color schemas of CIS [24] by culture-dependent color collections: each of impression-based color schemas of "luxurious", "colorful", "charming", "romantic", "cheerful", "authoritative", "robust" are represented by Japanese traditional colors, Chinese traditional colors, Indonesian traditional colors for interior design, French traditional colors, and Vietnamese traditional colors.

In Figure 5, Redisplay of impression-based color schemas of CIS [24] by culture-dependent color collections: each of impression-based color schemas of "luxurious", "colorful", "charming", "romantic", "cheerful", "authoritative", "robust" are represented by Japanese traditional colors, Chinese traditional colors, Indonesian traditional colors for interior design, French traditional colors, and Vietnamese traditional colors. By these results, several subtle differences can be observed in vivid red colors of "luxurious", "colorful" schemas, orange colors of "cheerful" schema and wine red colors of "robust" schema. Also interestingly, lack of some colors is observed in "romantic" schema from Chinese and Indonesian color collections.

Figure 6 shows examples of final results of impression-based color arrangement with color transformation by culture-dependent color collections: first 3 lines show color-arranged images of a Japanese pattern from World Design Patterns [32] with impression-based color combinations from Color Harmony collection [28], and last 3 lines show images of another Japanese pattern from originally-collected and digitized pattern data with impression-based color combinations from Color Image Scale (CIS) 1 [24]. The results of color transformation by each culture-dependent color collection are displayed in each column.

By these results, it can be observed that subtle differences in color expression by each culture are reflected to the pattern designs. For example, color-transformed images by Japanese traditional colors look dim or smoky in whole (img1, 7, 13, 19, 25, 31). Vivid red color of "striking" and dark blue color of "authoritative" are represented sharply in images with Vietnamese traditional colors (img4 and img28), and vivid yellow color of "warm" is represented sharply in images with French and American traditional colors (img17 and img18).

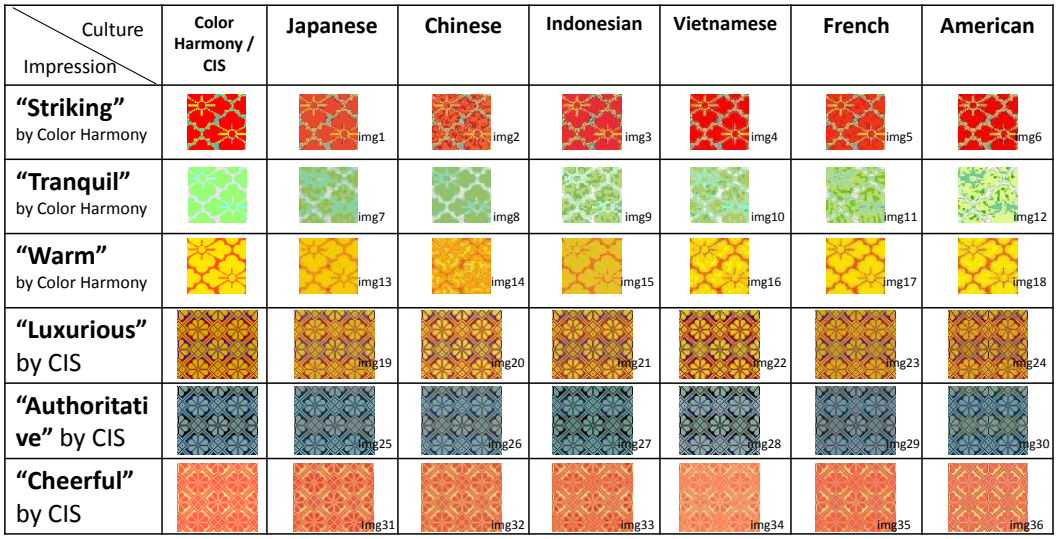

Figure 6. Examples of final results of impression-based color arrangement (row) with color transformation by culture-dependent color collections (column) for Japanese traditional patterns

In contrast, pale green and pink of "tranquil" and pale pink of "cheerful" are represented clearly in images with Chinese colors (img8 and img32), and pink of "cheerful" is represented by pastel in an image with American colors (img36). Grey color in "authoritative" is represented by dark green in an image with Indonesian colors for interior design (img27), and bordeaux colors in "luxurious" are represented by deep and strong colors with Vietnamese and Chinese colors (img22 and img20).

By these observation, we can see the characteristics of each culture-dependent color collection are reflected to the results that Japanese traditional color collection has a high discriminative ability for yellow/orange/brown colors, American, French and Vietnamese traditional color collections contain vivid colors, the Indonesian traditional color collection has a high ability to discriminate green and purple colors, whereas the Chinese traditional color collection can discriminate between monochrome colors.

5. Conclusion

In this paper, we have presented a cross-cultural image database with impression-based color arrangement by using culture-dependent color collections. The purpose of our research is to create a cross-cultural and dynamic media designing environment using culture-dependent color-impressions for cultural property's images, especially, images of patterns used in cultural products. The main feature of our cross-cultural image database system for cultural-product design is characterized by (1) Impression-based color arrangement, (2) Culture-based color-space transformation among culture-dependent color collections, and (3) Attribute-based data selection and mapping. Our system enables the color arrangement for patterns to be more natural and accurately-matched design for cultural products, based on the assumption that to communicate among diverse communities and foster creative activities is finding "common features" of each cultural background, and finding "subtle differences" among cultural properties.

As future work, we implement a Web-based application, enlarge the pattern data for real cultural products, and design and execute user studies for the output. The most important contribution of our research is that our system creates linkage among different cultures by sharing multimedia data. Its applications hold enormous potential for promoting regional economic development or innovative tourist business followed by cultural products creation. A Web-based application of our system for e-commerce will leads to a new environment for cooperative designing of cultural products and new industries targeting global markets with remote collaborators in different cultural backgrounds.

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