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A COLOR LEARNING SYSTEM BASED ON THE COLOR SCHEME AND PLACEMENT OF FURNITURE

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Abstract. *There are patterns in the color combinations that make people feel good. However, it is difficult to use the optimum color scheme without knowledge and experience. If the furniture does not fit the room, such as when you move, it is difficult to replace or reselect the interior, so you must choose the interior carefully. Therefore, we created a system that enables color learning using simulation of the color scheme and arrangement of furniture in the room and judgment of color harmony. The color harmony is judged using the colors arranged in the room. By using this system, the arrangement of furniture can be decided in advance, and the color scheme that suits the room can be learned. As a result of conducting an evaluation experiment of this system, it was highly evaluated in terms of practicality and learning effect.*
Keywords: Furniture arrangement, Color scheme, Color harmony, Color learning

1. **Introduction.** When humans observe an object, color plays an important role in determining what it is. Color has a great deal to do with human aesthetics, and depending on the combination of colors, the image of things may change significantly. Especially for clothes and interiors, the image tends to change depending on the combination of colors. In particular, it has been found that the correct color scheme of the interior also affects the improvement of labor performance [1]. Furthermore, each color has a different impression, which has a psychological effect on residents and visitors [2]. It can be counterproductive if the proper color scheme depending on the location is not used [3]. Based on these discussions, it can be said that it is important to have a harmonious interior color scheme. The state that the color scheme is "harmonious" means that the color scheme is arranged according to a specific condition. When the colors are in harmony, the viewer feels a good impression. It is difficult to create a harmonious color scheme without experience in interior design and knowledge of colors [4]. Also, furniture cannot be taken back to the room at the time of purchase and tried, and it is difficult to temporarily change the wallpaper and floor to try it. As a result, they may regret that the colors and shapes were not what they expected after purchasing the furniture. Regarding the arrangement of furniture, it is difficult to try the arrangement by moving multiple pieces of furniture many times. In order to solve these problems, a system by which the arrangement and color scheme of furniture can be simulated and color learning can be achieved is required.

There were conventional systems [5-9] by which furniture simulation or color learning can be achieved, but there was no conventional system by which both furniture simulation and color learning can be achieved. In this research, in order to facilitate furniture selection and remodeling, we have developed a system that combines furniture layout and

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color learning. Conventional systems and their problems are described in Section 2, our methods to solve conventional problems in Section 3, the system in Section 4, evaluation experiment in Section 5, consideration described in Section 6, and we conclude in Section 7.

2. **Conventional Systems and Their Problems.** In order to solve the problem that the arrangement of furniture cannot be easily determined and the problem that the color that matches the room is not known, it is necessary to perform two things, furniture arrangement simulation and color learning. In the conventional systems, there are some that can arrange the color arrangement of furniture and some that can support the color learning, but none of the systems can perform both the furniture arrangement simulation and the color learning.

There is a system that can place furniture [5]. The system allows to arrange furniture freely and change its color. However, since colors cannot be learned with the system, a color scheme that suits the room must be found by users' sense. There is also a system that has a function to propose the arrangement of furniture [6]. This system assists users by proposing furniture placement based on interior design guidelines. This allows the furniture to be arranged in an organized impression, but not as the user expected. Also, even with this system, the colors of furniture cannot be learned.

There were conventional systems by which color can be learned, color learning system with color analysis function [7], color scheme learning system based on clothes and websites [8], and a learning system for object-oriented programming themed on color [9]. Using these conventional systems, color scheme can be learned, but the color scheme that suits a room cannot be learned. Moreover, it is not possible to simulate furniture arrangement by these conventional systems.

3. **Our Methods to Solve Conventional Problems.** The block diagram of the system is shown in Figure 1. The system user first selects the color scheme set for the operation screen, and colors the furniture/interior created with the 3D model. In response to this, the result is reflected on the 3D simulation window on the operation screen. After that, the user presses the color check button to display the determination result, which enables the user to perform color learning. In order to solve the problem that furniture placement is not easy and the problem that the color that matches the room is not known, this system enables both furniture placement simulation and color learning. In order to realize these two functions, the color selection method used in the furniture color arrangement simulation was developed as a method using a color made by the user. This made it possible for users to use the laws of color schemes and compare colors. Since color learning is performed using the colors actually arranged in the furniture, if it is a harmonious color

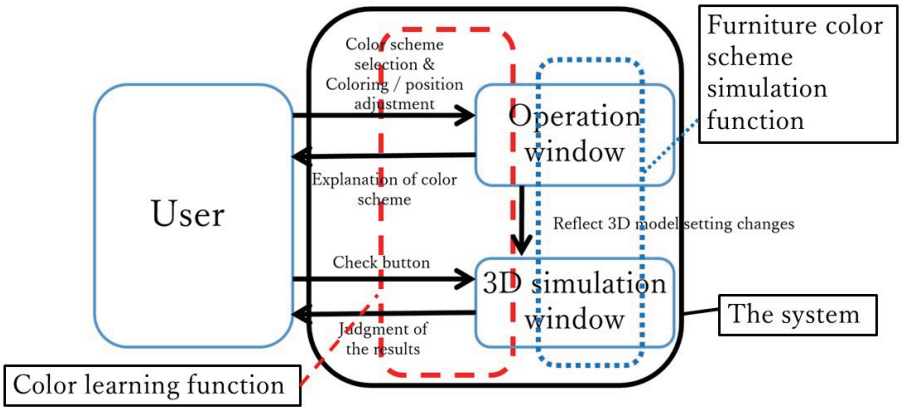

FIGURE 1. The block diagram of the system

combination, it is easy to check the room with the color combination, and it becomes easier to find the color that matches the room. In addition, since the color scheme for furniture can be performed by referring to the explanation and examples of the color scheme, the problem of having to find a color combination by fumbling is solved.

Color learning to gain knowledge about color harmony and make it easier to select a color that suits the room is possible by repeatedly determining whether the colors of furniture are in harmony with each other. By judging whether the colors of furniture are in harmony according to the basic color scheme such as "dominant color scheme" and "dominant tone", users will acquire knowledge about color harmony and learn about appropriate color combinations. By repeating this, users will to be able to voluntarily select the appropriate furniture color combination.

4. **The System.** This system mainly consists of two elements: color arrangement of furniture and color learning using judgment of color harmony. In order to determine whether the colors are in harmony with each other by referring to the colors arranged in the furniture, the color harmony is determined after the furniture is arranged in color. The screen diagram is shown in Figure 2.

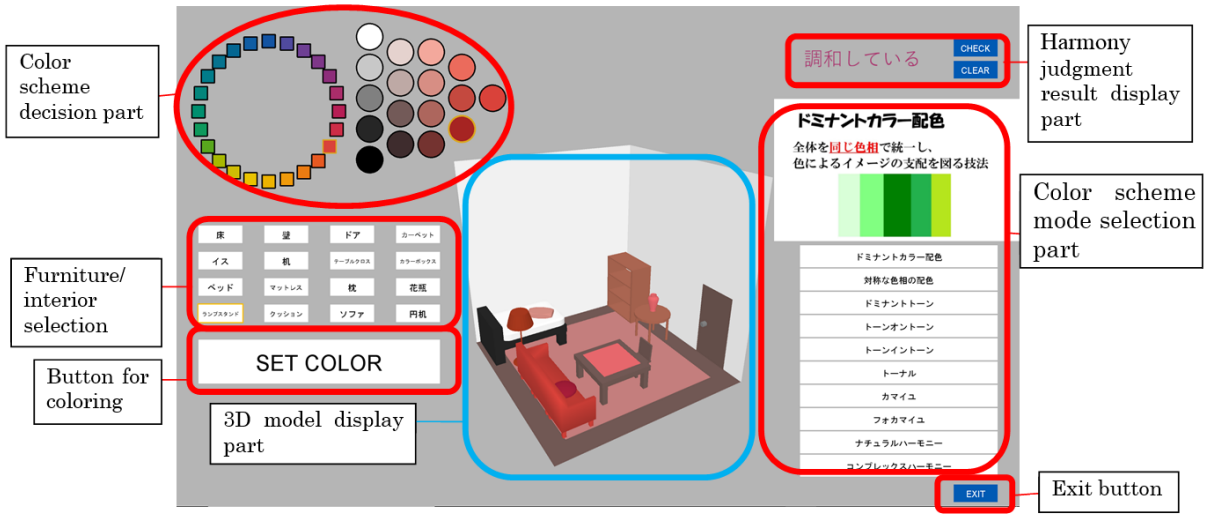

FIGURE 2. The screen diagram

In the color scheme determination part, the hue is determined from the color wheel diagram, and the color to be colored is determined from the tone diagram on the right side. In the furniture/interior selection part, the furniture to be colored in the color created in the color scheme determination part is selected. The selected furniture/interior can be colored on the 3D model display part with the coloring button labeled "SET COLOR". The color scheme can be selected in the color scheme mode selection part. After selecting a color scheme, an explanation about the selected color scheme is displayed. Then, the judgment result is displayed by pressing the "CHECK" button in the harmony judgment result display part whether or not the color scheme is made according to those color schemes. The judgment result can be erased by pressing the "CLEAR" button. Users can exit the entire system by pressing the exit button labeled "EXIT".

In the furniture arrangement color scheme simulation function, furniture created with 3DCG (3 Dimensional Computer Graphics) can be freely arranged and colored. The 16 types of coloring are possible, including the base part of the room such as "floor" and "wall" and typical furniture such as "chair" and "desk". The furniture can be moved and rotated.

With the color learning function, users can learn about colors by determining whether the colors arranged in the room are in harmony. There are two color schemes that can be

learned: "dominant color scheme" and "contrast hue scheme". The part for determining the color scheme is set in consideration of the characteristics of the color components of the room. The color of the room is composed of three elements: "base color", "assorted color", and "accent color" [10]. The accent color in it refers to the color that creates the individuality of the room. The accent color corresponds to the color of small items such as cushions and vases and decorations. Since the accent color is the most prominent part of the room, the change in the color of the accent color in the room has the greatest effect on the impression of the room. Therefore, in this system, the color harmony is judged using the color of the accent color part. The result of the color scheme is evaluated and feedback on whether it is in harmony is given. By making judgments with various color combinations and repeatedly checking whether they are in harmony, it is possible to acquire knowledge of color harmony.

The content that can be learned with this system is the color scheme that is also given in the color test. Table 1 shows an example of the color scheme [11]. The criteria for the color scheme in Table 1 use the relationship between hue and tone as shown in Figures 3 and 4.

PCCS developed by Japan Color Research Institute is used for color selection [12]. There are three attributes of color: hue, brightness and chroma. In PCCS, tone is defined as combination area of brightness and chroma. Two types of color attributes are mainly

Table 1. Color scheme technique and criteria [12,13]

Color scheme technique	**Hue relationship shown in Figure 4**	**Color tone relationship shown in Figure 4**
Dominant color	To similar	Free
Dominant tone	Free	Same or similar
Tone on tone	Same or similar	Free
Tone in tone	Free	Same or similar
Tonal	Free	Sf,d,ltg,g
Camaille	Same or adjacent	Same or similar
Focamaille	Similar	Same or similar
Natural harmony	Adjacent or similar	Free
Complex harmony	Other than the same	Free
Complementary hue	Complementary	Free

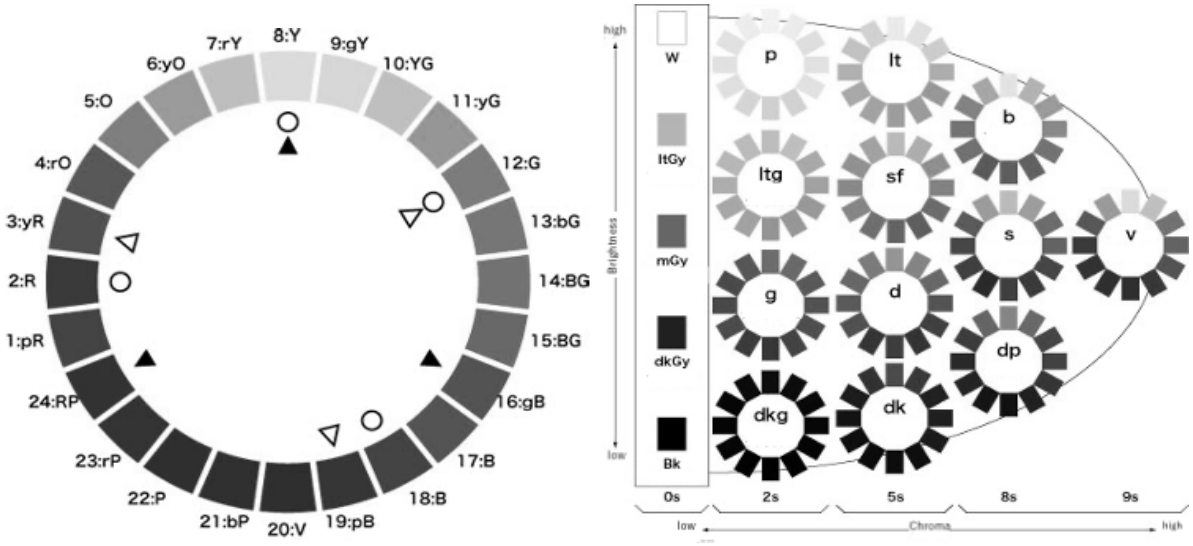

Figure 3. Hue wheel diagram and tone map in PCCS [12]

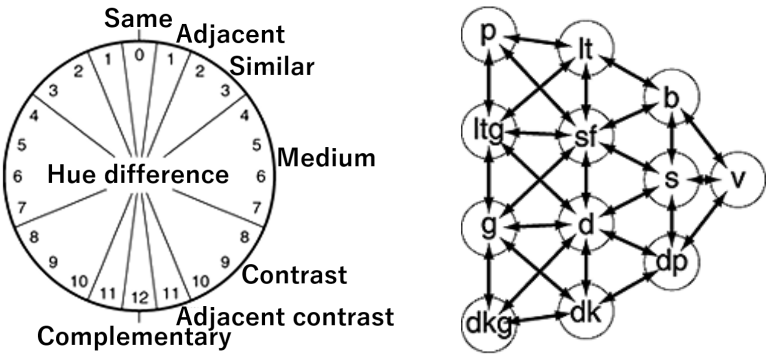

FIGURE 4. Hue and tone relationships [13]

used in PCCS: hue and tone as shown in Figure 3. There are 12 kinds of color tones: v (vivid), b (bright), s (strong), dp (deep), lt (light), sf (soft), d (dull), dk (dark), p (pale), ltg (light greyish), g (greyish), and dkg (dark greyish). Each tone in the PCCS tone color space has a corresponding hue circle diagram. When determining color harmony, "similar tones", which are tone relationships in PCCS, and "same hue", "adjacent hues", and "similar hues", which are hue relationships in PCCS, are used. Similar tones represent the relationship between two types of tones that are adjacent to each other. All hue relationships are determined by the hues difference of the colors used in the color scheme. Hue wheel diagram and tone map in PCCS are shown in Figure 3, and hue and tone relationships are shown in Figure 4.

Two similar tones are tones connected with an arrow in Figure 4. Because this system is based on the arrangement and color scheme of furniture, it was developed using Processing [14], which is the programing language that is good at visual expression.

5. **Evaluation Experiment.** In the evaluation experiment, the prototype system was used for evaluation, and then the system shown in Chapter 4 has been completed. The main difference of the prototype version is that the judgment modes are only "dominant color scheme" and "symmetrical hue". In the evaluation experiment, the system was demonstrated to 23 university students as subjects. After the demonstration, the subjects are asked to fill out evaluation questionnaires. There are five evaluation questionnaire items: Q1 "Do you feel this system is practical?", Q2 "Using this system, did you feel funny?", Q3 "Using this system, can you learn about color schemes?", Q4 "Did you feel it is easy to operate?" and Q5 "Did you feel the screen layout was appropriate?". The evaluation value was set in 5 stages from the highest value of 5 to the lowest value of 1. The results of the evaluation experiment are shown in Table 2 and Figure 5. In Table 2, evaluation 1 to 5 columns show the numbers of people who evaluated as the value and average columns show the average evaluation values for each evaluation item.

In the evaluation experiment, two items, Q1 "Do you feel this system is practical?", and Q2 "Using this system, did you feel funny?" got the highest score. In the next, Q3 "Using this system, can you learn about color schemes?", Q4 "Did you feel it is easy to operate?"

TABLE 2. Experimental result

	Evaluation 1	**Evaluation 2**	**Evaluation 3**	**Evaluation 4**	**Evaluation 5**	**Average**
Q1	0	0	2	16	5	4.1
Q2	0	0	3	14	6	4.1
Q3	0	2	5	10	6	3.9
Q4	0	0	10	10	3	3.7
Q5	0	1	12	8	2	3.5

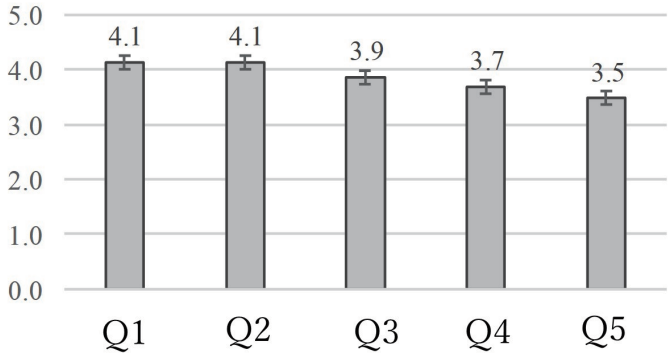

FIGURE 5. Experimental result

and Q5 "Did you feel the screen layout was appropriate?" were highly evaluated in that order. In the free description field, there were opinions such as "I think the button size and font size should be larger", "The text on the buttons is difficult to read", and "I can enjoy the furniture layout, but I do not feel that I am learning". On the other hand, there are also positive opinions such as "I think it can be used when actually thinking about the arrangement of furniture" and "I want to actually use it".

6. **Consideration.** From the results of the evaluation experiment, it can be seen that the practicality and learning effect have been evaluated to a certain extent, and that the operability and screen layout are not highly evaluated. It is thought that the high evaluation of practicality and learning effect is due to the structure of the system that allows the user to actually color the furniture, judge the harmony, and learn experientially. The reason why the operability and layout items are often rated lower than other items is thought to be that the button layout and character size are inferior, making it difficult to operate as expected. The system has been improved to solve the above problems. Figure 2 shows the screen configuration of the improved system. Improvements include button-related improvements and the addition of a judgment mode. In order to improve the visibility of each button, the background color of the button and the color of the caption text have been changed. The color button has been changed to be below the furniture selection button, and the caption is also displayed as "SET COLOR" to make it stand out. Judgment mode implements all the color schemes shown in Table 1 and allows the user to learn. Even in the added mode, the explanation of the judgment method corresponding to each mode is displayed. Although evaluation experiments have not been conducted on the improved system, it is considered that the ease of use and learning effect are improved compared to the system at the time of the evaluation experiment because the layout was improved and the functions were added in the form of improving only the defects.

7. **Conclusion.** Since the conventional system cannot perform both the furniture color arrangement simulation and the color learning system at the same time, there is a problem that it is difficult to determine the furniture arrangement and the color arrangement that suits the room. In this research, in order to facilitate furniture selection and remodeling, we have developed a system that combines furniture layout and color learning. As a result of conducting evaluation experiments using this system, it was found that this system was practical and funny to use as an overall evaluation. There were also opinions that the operability and layout were evaluated low. Based on these opinions, we have improved the system, improved both functional and visual aspects, and improved the learning effect and convenience. The problem of learning the arrangement and color arrangement of furniture that suits the room has been solved by the furniture color arrangement simulation

function, the explanation and example presentation of the color arrangement technique, and the color learning function by judging the color harmony using the color arrangement technique.

In the future, it will be necessary to make improvements of the system such as implementing more detailed advice functions.

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