

Office Space Classification for Working Comfortable based on Extracted Color Features

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Abstract—Now that color control in an office space is possible thanks to the advancement of full-color LED lighting fixtures, color preference by the office workers have played important roles in working comfort. To estimate what colors are preferred by the office workers in an office space, it is necessary to analyze what color is present in what location within the given space. Furthermore, to create a diverse office space that is comprised of the office worker's preferred color space, there must be an index which could evaluate for the type of office space each worker prefers as well as what impression the actual workspace leaves on the workers. The aim of this study is to build a model which extracts color space features from the spaces the workers prefer and to evaluate the office spaces. In this paper, we propose a method to create an office space evaluation model which takes into consideration the accent color of the space based on feature values which are extracted using the CIELUV colorimetric system and the k-means method. Also, we evaluate the test subjects' workspace by using the proposed model.

Keywords: feature value extraction, clustering, space evaluation model, decision tree analysis, CIELUV colorimetric system.

1. Introduction

In recent years, there is an increased interest in improving the office environment from the point of view of improving the intellectual productivity and comfort of the workers, and it has been reported that controlling the colors in the office space using full-color LED lighting fixtures could potentially achieve these goals [1]. In contrast to the traditional uniform office space, it is now becoming possible to create suitable color space for each worker by controlling the lighting fixtures through computers.

To estimate what colors would be preferred by each worker in a given office space, it is necessary to analyze what colors are present in which location and to how much in that office space. However, the illuminance sensors and color temperature sensors that are currently used are designed to measure the illuminance of the initial room setting or the color temperature based on the back-body locus on a chromaticity diagram, and thus it is not designed to measure

the color preferences of the workers. On the other hand, the appropriate colors would differ from one office space to another. Since colors greatly influence the comfort level of office spaces, in order to create the optimal color space using full-color LED lighting fixtures with consideration to the present colors, there needs to be a method to most effectively extract the color feature values of the space. Also, it is said that the office workers' preferred colors would be different for each individual. Therefore, in this study, we propose a method to automatically extract the color features of a space based on each user's own field-of-view images.

Additionally, to autonomously create the optimal color space from the extracted feature values, it would be necessary to create rules for the workers on writing down what type of space is or is not conducive to work and evaluate, based on those rules, the office space the workers occupy. Therefore, in this study, we attempt to develop an office space evaluation model which extracts the color space feature values of the office space for which each worker had expressed their preference.

More specifically, the representative colors could be extracted from the field-of-view images using the k-means++ method. However, since RGB colorimetric system differs from the color difference experienced by people, CIELUV colorimetric system which is closer to how people sense color difference is to be used to extract the representative color, and both methods are evaluated for performance. In the office space evaluation model experiments, rules are created by applying the decision tree analysis to the office images that were already evaluated by preliminary experiments to verify the effectiveness of the proposed evaluation model.

2. CIELUV Colorimetric System

In the proposed method, the color feature values are extracted from the field-of-view images, though the LUV colorimetric system will be instead of the RGB colorimetric system as the former is closer to how humans sense color. In this section, we explain the LUV colorimetric system. The CIELUV colorimetric system is one type of colorimetric

system which the International Commission on Illumination determined as a way to quantify and write down color. CIEXYZ colorimetric system is based on the RGB values of pixels, but as it is known that the color difference which people can distinguish highly depends on the color region and thus the color difference on the diagram does not match up to the distance as seen on the diagram. On the other hand, CIELUV colorimetric system was defined to have a uniform color space as most closely experienced by people. Since digital images generally use the RGB colorimetric system, LUV colorimetric system is derived from the RGB colorimetric system.

The conversion method from the RGB colorimetric system to the CIELUV colorimetric system is shown below:

- 1) The pixel values of the pixels expressed in the RGB colorimetric system is converted to the CIEXYZ colorimetric system using equations (1) and (2). Here M represents the weight.

$$(X \ Y \ Z)^T = M(R \ G \ B)^T \quad (1)$$

$$M = \begin{pmatrix} 0.412391 & 0.357584 & 0.180481 \\ 0.212639 & 0.715169 & 0.072192 \\ 0.019331 & 0.119195 & 0.950532 \end{pmatrix} \quad (2)$$

- 2) CIEXYZ colorimetric system is converted to $u'v'$ value using equations (3) and (4):

$$u' = \frac{4X}{X + 15Y + 3Z} \quad (3)$$

$$v' = \frac{9Y}{X + 15Y + 3Z} \quad (4)$$

3. Proposed Method

3.1 Color feature extraction using the CIELUV colorimetric system

Since it is necessary to analyze where and to what extent the colors exist in an office space to estimate each worker's color preferences, the proposed method not only extracts the representative color that is in the field-of-view images, but the location of the color feature value will also be extracted and considered. Specifically, to extract the color feature value of a given space, the representative colors are extracted from the field-of-view images using the clustering method. In the field of image processing, the mainstream method used for the representative color extraction is to use the RGB colorimetric system and cluster the RGB values from each pixel, and the number one cluster to be treated as the representative color. However, it is known that the color difference humans can distinguish and the color territory that is shown based on the RGB colorimetric system significantly differ. As the aim of this study is to estimate the colors that the workers would prefer, it is necessary to match the territory of the chromaticity diagram with the color difference as distinguished by humans. Therefore, the

CIELUV colorimetric system which was defined to have a uniform color space which more closely represents how people sense color will be used. Furthermore, since the ratio of how much each representative color would occupy would differ based on the field-of-view image, we consider the degree of importance would also change. Therefore, the specific weight of the color as seen in the field-of-view images is also extracted at the same time. The algorithm of the proposed method is shown below:

- 1) Image P will be divided into N parts. $P = P^1 \cup P^2 \cup \dots \cup P^N$.
- 2) $n = 1$ and if $n < N$, then Step 2 to 8 is to be repeated.
- 3) Each of the pixel values from the sub-images P^n is to be converted from the RGB colorimetric system to the LUV colorimetric system¹.
- 4) k will be defined as K^2 .
- 5) The pixels of the sub-images P^n are to be divided into k number of clusters.
- 6) The representative color will be extracted from the LUV value closest to the centroid of each cluster which was divided into k parts.
- 7) The specific weight of the pixels included in each cluster which were divided into k parts is to be extracted.
- 8) $n \leftarrow n + 1$.

3.2 The office space classification model using decision tree analysis based on the extracted representative colors

Controlling the colors of the lighting depending on the workers' preference would fulfill an important role in creating a as diverse office space. Since it is plausible that the workers would require different color from the light fixtures, the interior decorations change in office space, a model to evaluate what type of office space each worker prefers and what kind of impression a given workspace is leaving on the workers, is required.

On the other hand, while accent colors which are used only in limited quantity and on specific spots would not be taking up the bulk of the colors, it is reported that the accent colors are able to draw attention and influence the space [2]. For this reason, in this study, we aim to create the rules which would take into consideration not only the base colors that would be included in abundance in an office space but its accent colors as well.

Figure 1 is the result of using logistic regression to identify the patterns of the color feature value in a sample field-of-view image to find the regression line.

Here, if we look at the red pixel and the regression line, we can see that the pixels that are away from the line, and

¹See section 2

² K represents the number of representative colors, and in this experiment, the K value was set to be four ($K=4$)

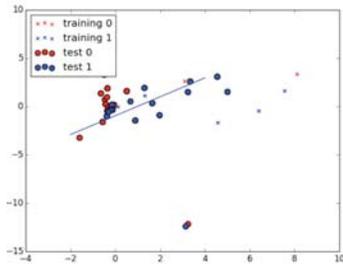


Fig. 1: Identification using logistic regression

are not considered to be part of the rule. Since the accent color is often a value far away from the base color, creating rules using statistical pattern recognition based on machine learning is not suitable. Therefore, in this study, the rules are created using a rule-based decision tree analysis. The representative colors extracted in section III-A are used as the feature values which are required to create a decision tree.

4. Evaluation experiments

4.1 Performance evaluation regarding extracted color feature values

Photographs of offices were automatically obtained from the websites [7] and [8]. After removing images not related to office spaces, eight images were randomly extracted from 100 images as the experimental data. A preliminary experiment was conducted by test subjects, which they were asked to evaluate each of the eight images on a ten-point scale, whether or not they thought the offices in each of those eight images looked like a place conducive to work or not. The test subjects were 32 people (male and female) who were around 20 years of age. The highest rated office image was Fig.2(a), and the least favored office image was Fig.2(b). For the rest of this experiment, Figure 2 is to be used as the experimental data. Also, Figure 3 shows sub-images when the parameter N is set to three ($N = 3$).



(a) (b)
Fig. 2: Office images

To evaluate the performance, the proposed method and the RGB colorimetric system are used to extract the representative color and compare their performances. In this study, the k-means++ method which is commonly used as the clustering method was used. Also, when the chromaticity diagram of RGB space is compared using the colorimetric



(a) Image1 (b) Image2
Fig. 3: Divided images

system of a CIELUV chromaticity diagram since the color space would differ between the two methods, comparison to the new method would prove to be difficult. Therefore, the following procedures are taken for this evaluation. In this paper, we refer to this method as the RGB method:

- 1) Each pixel of the sub-image P^n will be expressed in RGB.
- 2) The sub-image P^n will then be clustered.
- 3) The data after clustering will be converted to the LUV colorimetric system.
- 4) Step5 to 6 of the proposed method will be executed.

4.2 Performance evaluation relating to the creation of rules based on the decision tree analysis

When creating rules using decision tree analysis, as part of verifying its performance, it is necessary to evaluate whether the decision tree had taken into consideration the accent colors in its making, artificial data is generated to create for the experiment. The leaves in Fig.4(b) is an artificial data where the leaves are green, and the floor is given a red accent color, while Figure 4(c) is also artificial data that has additional accent colors added to Fig.4(a). The decision trees will be constructed based on the hypothetical assumption that Figure 4(b) would be considered a space more conducive to work while Figures 4(a) and (c) to be spaces that are less conducive to work. The dataset of Fig.4 was divided into smaller parts as seen in Fig.5 so that localized accent colors would be more easily extracted. The top three clusters of each image were then treated as the centroid.



(a) (b) (c)
Fig. 4: Accent color experiment data

Additionally, when using the k-means method, the even in the cases where the same data was used for initial value dependencies, the centroid came out different. For this reason, k-means++ method, which takes into consideration the initial value dependencies, was applied. Since the centroid of the top three clusters were slightly different even

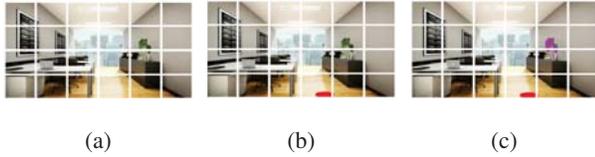


Fig. 5: Divided images

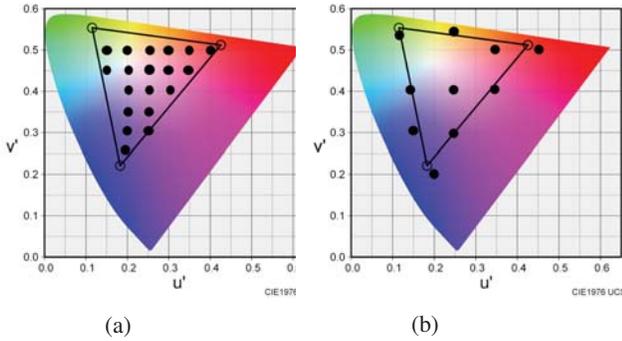


Fig. 6: Fixed values to perform discretization

after applying the k-means++ method the discretization of the representative color was conducted. The procedure for discretization is shown below:

- 1) The point group ps that is the fixed value on a uv chromaticity diagram is designated, and each point is assigned a number.
- 2) The closest point c_i to the representative point ps_i is extracted from the ps .
- 3) The c_i 's values is replaced with the ps_i 's numbers.

When the performance of Fig.6(a) which has positioned in equal intervals increased number of point groups which are the fixed values, were compared to the Fig. 6 (b) which had decreased number of these point groups placed at random on a coordinate which had a high color saturation and then used the centroid of Fig.4(a) to discretize, it was found that Figure 6(b) had better performance. This is most likely due to the differentiation of the representative colors of the space that occurs with the highly saturated colors during the clustering. In this study, the point group of Fig.6(b) is adopted.

Finally, by creating a decision tree based on the color feature values to which the workers have shown preference, we construct an evaluation model that would determine whether the working environment is a space conducive to work or not. The subjects were, from the internet, asked to select six images of spaces they think would be conducive to work and another six images of spaces they felt were not conducive to work. Figures 7 and 8 show images of offices the test subjects selected. At this point, the decision tree which was created above was used, and to it, included the experiment data from Fig.4 to let it consider the accent colors. The image of the subjects' lab is shown in Fig.9.



Fig. 7: Office images that have received high marks



Fig. 8: Office images that received low marks



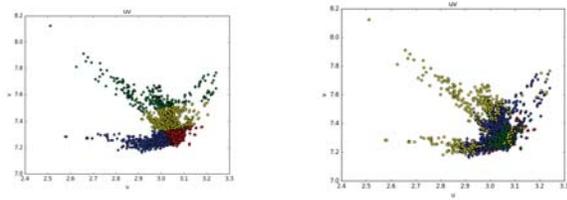
Fig. 9: The image of the test subject's laboratory

5. Results of the experiment

5.1 Comparison between the proposed method and the RGB method

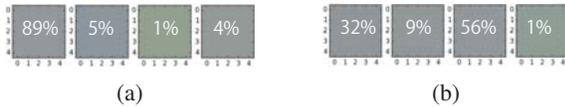
Figures 10 to 17 shows the experiment results. The results in Figs.10, 12, 14 and 16 is not easy to compare due to the fact that the distribution area is different for every image, so the vector of the pixel whose distance from the centroid of each image is the farthest is normalized as 1. The color of the points represents the cluster types. Additionally, the colors of Figs.11, 13, 15 and 17 express the representative colors, and if the specific weight of the representative color is 0%, it means the number of pixels that belong to that cluster is less than 1% of the total number of pixels in the image.

We can observe from Figs.10, 12, 14 and 16 that the proposed method using the LUV colorimetric system show-



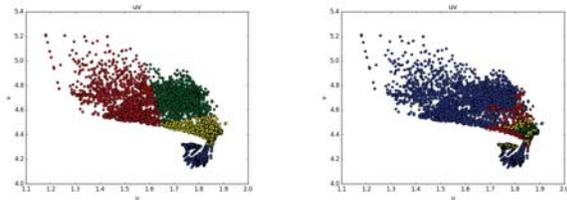
(a) CIELUV colorimetric system (b) RGB colorimetric system

Fig. 10: The upper row normalization diagram of Image 1



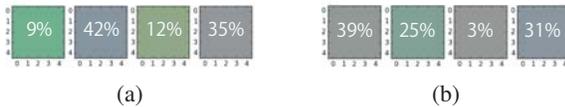
(a) (b)

Fig. 11: The representative color in the upper row of Image 1 and its ratios



(a) CIELUV colorimetric system (b) RGB colorimetric system

Fig. 12: The bottom row normalization of Image 1

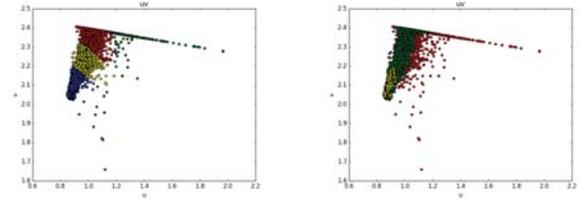


(a) (b)

Fig. 13: The bottom row representative colors of Image 1 and its ratios

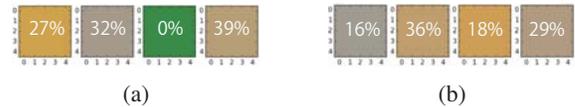
that the pixels that are close together on the chromaticity diagram belong to the same cluster, which shows that the way they were divided does not go against how humans recognize similar colors. To be able to behave like how humans do, similar colors would need to be in the same cluster, which was achieved here. On the other hand, with the RGB method using the RGB colorimetric system, other clusters exist inside of another cluster and thus are unable to properly separate on a chromaticity diagram.

Next, the representative colors and its specific weight are compared. In Fig.11(b), the colors of the number one cluster and the number two cluster in the RGB method look similar, but we can see that they are separated into different clusters. When we apply the proposed method of the green carpet at the bottom of Image 1, that bright green is extracted as the representative color as seen in Fig.13(a), but the RGB method would extract a duller green color as seen in Fig.13(b). When the specific weight of the representative colors of the proposed method and to the RGB method



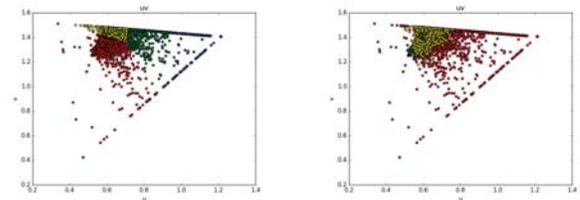
(a) CIELUV colorimetric system (b) RGB colorimetric system

Fig. 14: The upper row normalization diagram of Image 2



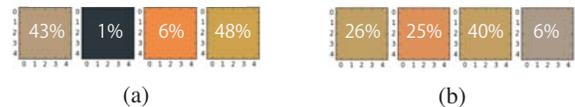
(a) (b)

Fig. 15: The representative color in the upper row of Image 2 and its ratios



(a) CIELUV colorimetric system (b) RGB colorimetric system

Fig. 16: The bottom row normalization of Image 2



(a) (b)

Fig. 17: The bottom row representative colors of Image 2 and its ratios

is compared, the variance of the specific weight is found to be greater in the proposed method. This result shows that the proposed method distinguishes local pixels in the chromaticity diagram as different clusters. Based on these results, we can verify that the RGB method has a tendency to extract similar colors to some other representative colors, but the proposed method was able to properly extract the color that was included as an accent as a representative color.

5.2 Performance evaluation of the evaluation model

Figures 18 and 19 shows the results of applying the proposed evaluation model to Fig.4. Here, the "X[]" seen in the branches of the decision tree represents the address of the representative color, gini shows the value of Gini's coefficient, the sample shows the number of data relating to each branch, the value is the number of the population after each branching occurred. Figure 19 is the visualization of Fig.18, and it shows which divided image from Fig.5

was used and at which representative color the branching occurred.

Based on Fig.19, it can be seen that when there were green leaves and when there was a red accent color on the floor, it was evaluated as having a space that was conducive to work. That is to say; the results show that the artificial data that was placed as accent colors were taken into consideration.

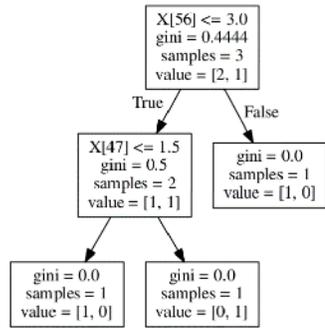


Fig. 18: Decision tree

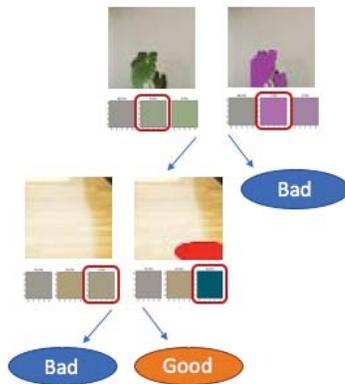


Fig. 19: The visualization of Fig.18

However, Figure 19 shows that second image from the right at the bottom row in Fig.5(b) and Fig.5(c) does not include the red which is the accent color as the representative color. In contrast, the green, which is not included in the dived images are extracted as a representative color. This result shows that the red was extracted as green when converting the CIELUV colorimetric system into an RGB colorimetric system, indicating there is a problem with the conversion formula.

Next, we will show the results of applying the proposed method to Figs.6 and 7 in Fig.20 and constructing the subjects' office space evaluation model.

As a result of incorporating the color feature value of Fig.9 into Fig.20's evaluation model, Figure 9 was concluded in the evaluation as a space that is not conducive to work for the test subject. That is to say; the proposed method can evaluate even the real data sets.

Also, the offices other than shown in Figs.7 and 8 which the test subjects had selected as shown in Fig.21 were used

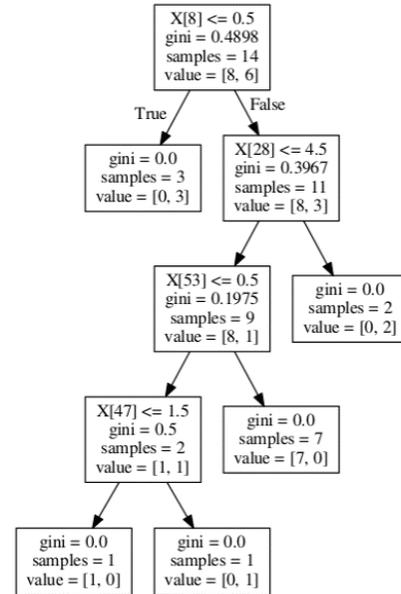


Fig. 20: Evaluation model

to test the performance of the evaluation model. The results of the evaluation model indicated that Figure 21(a) was an office space conducive to work while Figure 21(b) was evaluated as an office space that is not conducive to work. That is to say, the evaluation model and the test subjects came to the same conclusion, indicating the validity of an office space evaluation model constructed by utilizing a decision tree analysis.



(a) High marks



(b) Low marks

Fig. 21: Office images

6. Conclusion

In this study, we aim to estimate the colors which office workers would prefer within an office space. In addition, we have tried to create some rules that operates as an index to what type of office space would the workers prefer and proposed a method of analyzing each worker based on the field-of-view images and to extract the feature values. Additionally, we proposed an evaluation model which evaluates an office space based on the color feature values.

In this paper, we proposed a method with which the field-of-view images expressed with the RGB colorimetric system is to be converted to CIELUV colorimetric system,

which is closer to how humans sense color differences, and from it, extract the color feature values. Upon conducting an experiment to compare the proposed method and the RGB method, we found that when the proposed method was used, the pixels that are closely placed on the chromaticity diagram were found to belong to the same cluster, and that it was able to extract impressionable representative colors from the field-of-view images. On the other hand, when the RGB method was used, other clusters within a cluster was found, indicating that colors were not able to separate out of a chromaticity diagram properly, and impressionable representative colors could not be extracted. Based on the findings above, we consider CIELUV colorimetric system is better for color feature value extraction of field-of-view images.

Based on the extracted color feature values, we proposed an evaluation model to determine what type of impression an office is leaving on its workers. In the proposed evaluation model, not only was the predominant base color in the office considered, but also the localized accent colors were included for consideration, and created rules using a decision tree analysis for this purpose. The experiment showed that the decision tree could be created even with artificial data provided as the accent color and be considered. When the test subjects evaluated the office images and followed the construct of the evaluation model to determine its performance, it was found that the test subjects and the evaluation model came to the same conclusions, indicating the proposed evaluation model's validity. In this report, the index for this evaluation model was the color features, but there are likely other valid feature values as well; thus the expansion of this index would be an area for further research.

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