A METHOD TO EVALUATE THE COLOR IMPRESSION OF INTERIORS
—In the case of public welfare buildings—

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The aim of this study was to develop objective criteria for the evaluation of the interior color impression using images. The object of the study were welfare facilities in Miyagi prefecture. New parameter named "mean color" is used. The calculation and analysis of this parameter was possible due to the current level of computer equipment. The validity of the parameter was investigated in experiments. The subjective evaluations were in correlation with the computer measurements, which proves the impact of the selected factor upon the human perception.

1. Introduction

The necessity of construction of public facilities such as welfare facilities for the aged has been increased in an aging society like the Japanese one. The color coordination of architectural interior planning in the welfare facilities is not systematically carried out, consequently moderate color coordination (soft, warm and calm colors) is apt to be adopted in an actual construction. Our preceding survey of welfare facilities in Miyagi prefecture indicates that a fairly good color coordination actually dominates in the welfare architecture (Appendix). However, the psychological impression of the passable color coordination of interior has been unknown. There is possibility for another architect's choice of color coordination like conspicuous combination of complex colors.

Moon and Spencer proposed the balance point concept. According to them, the balance point is important because it gives a measure of the overall color effect. By the choice of a proper balance point the painter can emphasize desired psychological effects. The concept states that for two color patches with areas $S_1$, $S_2$ and trichromatic coordinates $(X_1, Y_1, Z_1)$, $(X_2, Y_2, Z_2)$ there is a point in the color space which is representative for the total color effect. The coordinates of the balance point are:

$$X = \frac{X_1 S_1 + X_2 S_2}{S_1 + S_2}; Y = \frac{Y_1 S_1 + Y_2 S_2}{S_1 + S_2}; Z = \frac{Z_1 S_1 + Z_2 S_2}{S_1 + S_2}$$

It is desirable to establish a method for evaluation of the relationship between the color coordination of the interior and its psychological effect upon the users of a welfare facility. In the present paper an method for evaluation of the relation is proposed and some supporting evidences are shown.

2. Definition of the "mean color" parameter

2.1 Concept of "mean color"

The proposed concept is adequate for artificial environments with soft and moderate color compositions, which supposedly can be found in welfare facilities. It extends the concept of Moon and Spencer to computer analysis of interiors using color images.

All forms in the space are represented by their surface colors; they are shaded depending on the illumination and distance. The human eye analyzes these colors and then composes the forms. If we put aside the spatial information - forms and dimensions, we see only surface colors (or color points - pixels, when we look at an image). While our eye studies an interior, it stops at every color spot and gradually all of the composition colors have their impact applied. After the integration of the color information, we can associate it with a single color.

It is possible that the impression from a given image of architectural space or from the real space is related to this single parameter derived from interior images. In the present paper, a "mean color" parameter could be proposed as one of the measures of the real space color impact.

2.2 Definition of "mean color"

The mathematical definition of the mean color would be a very simple set of equations. The inevitable necessity of using computers makes the task even simpler. The images on the computer monitor are presented by pixels and this is the most detailed information we could obtain.
The color of the pixels could be described by the means of CIE \( L^{*} a^{*} b^{*} \) color space, which for the purpose of this thesis is more convenient. For an image consisting of \( N \) pixels \( p_{i,j}^{(n)} \), the mean color \((L^{*}_{m}, a^{*}_{m}, b^{*}_{m})\) in \( L^{*} a^{*} b^{*} \) system is defined as follows:

\[
L^{*}_{m} = \frac{1}{N} \sum_{i=1}^{N} p_{i,j}^{(n)} \text{ and } a^{*}_{m} = \frac{1}{N} \sum_{i=1}^{N} p_{a}^{(i,j)} \quad \text{and} \quad b^{*}_{m} = \frac{1}{N} \sum_{i=1}^{N} p_{b}^{(i,j)} \text{...(2)}
\]

In \( L^{*} a^{*} b^{*} \) color space the deviation of the mean color from the '0' mark is a measure of how the color is asymmetrically located from the neutral gray axis. Also it means that in each couple of complementary colors (red-green, blue-yellow), one color overwhelms the other. If in one image the mean color is neutral, without hue, that means that the values of the couples are equal and the distribution of colors is balanced. In a real interior, where the color patches are in sophisticated interrelation, the mean color will be a measure for the color balance. Such an option for color planning can be useful when the architect wants to control the range of color perceptions, which the consumer of the architectural work has. This is especially valid for welfare facilities where moderate color compositions are desirable.

3. Human impression survey

In order to clarify the relation between the proposed “mean color” parameter and the human impression from the interior colors of spaces in welfare facilities, the measurement of color and a human impression survey have been carried out for a welfare building - Taiwa-town, Health & Welfare Center\(^{(41)}\) (located in the northern part of Miyagi prefecture).

Three rooms have been selected as a target to evaluate the relation, the entrance hall, the relaxation hall and the lecture hall. These spaces have been considered to be the core of the center.

3.1 Conditions to measure the mean color

(1) Taking images

For analysis of real buildings the video footage is preferable. The frames follow the logical sequence of the visitor's movement with time specification and there are no selected or arbitrary shots.

In the actual survey short video footage were taken with non-professional video camera\(^{(40)}\). The camera was positioned in key points of the three spaces.

For the entrance hall, for example, a position immediately after the main entrance of the building was taken as a standpoint (Fig. 1). With rotating camera view, the footages included panorama view of the spaces. Later sequences of frames were extracted (one frame per second) and the digital images (resolution - 640/480) were stored into a computer.

(2) Calculation of the mean color

The mean colors of the frames were calculated with image processing software, developed by the authors, that permits the access to the color value of the pixels. For the calculations were used the equations (2).

3.2 Surveying human impression

(1) Questionnaire experiment

The experiment was carried out in June 1999, in Taiwa-town, Health & Welfare Center. The primary question provided for the respondents in the experiment was “What color comes to your mind when you close your eyes and start thinking about the Relaxation Hall? Please indicate the color using this color table.” Every respondent had to use a standard answer sheet (in Japanese) and a table with 144 chromatic and 12 achromatic color samples, with known coordinates in \( L^{*} a^{*} b^{*} \) color space, for choosing answers, when asked about colors.

Concerning the scope of this paper, the questionnaire consisted of questions aimed to clarify, do the visitors experience a sensation of the space that is near the mean color value calculated for an image of the space? After the experiment the answers were turned into computer data and compared with the data obtained from the sequences of frames.

(2) Testee

There were 38 respondents, office workers, supporting staff and visitors (about half of the visitors asked to cooperate, agreed to do so). Of them 18 men and 20 women, representing 6 age categories, from under 20 up to over 80 years. Additionally in the first week of July group of 11 university students (10 men and 1 woman) participated in the experiment.

Concerning aged visitors, the answers were given orally and filled in by other person. These participants in some cases were not able to give reasonable or any kind of answer, which was considered.
4. Results and discussion

The valid answers for the color impression from the three rooms are shown in Table 1. Because the color impression is represented in L'a'b' color system, it is capable of counting and plotting on two dimensional scattergram with green - red axis (a') and blue-yellow axis (b'). Fig. 3 - 5 are the results counted for each room.

The white square shows the value of the measured and calculated mean color, and the black square is the mean value from the answers given in the questionnaire. Rods represent answers (colors); the height of the rods is proportional to the number of given answers.

Most of the answers, which the respondents selected from the table with color samples are yellowish, reddish and brownish grays or different pure grays, which correspond to the calculated values of the mean colors. There are few answers which deviate from the mean stream. Most probably these answers were arbitrary, but even if they are included, it does not change the result in general.

It is obvious that the couple of mean color values is within the main cluster of given answers, near to each other. That means when the attention is concentrated on the fact that there is color, not available in the interior, but representing the mixture of all color, it can be determined.

If the scattergram is regarded as a joint probabilistic function, Hotelling's T^2 method could be used in order to verify that the mean color is representative value for the answers of color impression. Table 2 shows the calculated F - statistic values (α). The three α values satisfy the 0.05 level of significance routinely used in behavioral sciences\(^3\).

The conclusion is that the experiment in three functionally unrelated spaces of Taiwa-town, Health & Welfare Center shows that the "mean color" parameter truly reflects the impression, directly or indirectly, created by the color environment of the selected rooms. The proposed method for analysis is intended primarily for practical usage, so any complicated procedures should be avoided. It should be considered that the subject of this research is difficult to explain only by mathematical means and thus, in any case, it will remain in certain parts a subjective matter. A problem which is intrinsic to the human nature. Everybody has his own preferable colors and individual taste for color composition, although there are results showing some dependencies in color preferences\(^3\).

As it was previously mentioned, colors have specific psychological and physiological effects upon the human. The planning of color usage is a powerful tool for the architects.

In addition to this it must be underlined that we do not deny the importance of the scene color composition, accents, gradations, dominant colors or the fact that the juxtaposition of two colors is important factor for their perception. We propose that here explained parameter could be useful if it is applied simultaneously with those which are well known. The reasons are:

1) It is convenient way to control the balance of colors presented in given

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Table 1: Answers for color impression

<table>
<thead>
<tr>
<th></th>
<th>Valid answers</th>
<th>Hue average</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>a* (g-r)</td>
<td>b* (b-y)</td>
</tr>
<tr>
<td>Entrance hall</td>
<td>33</td>
<td>7.75</td>
<td>6.9</td>
</tr>
<tr>
<td>Relaxation hall</td>
<td>22</td>
<td>2.94</td>
<td>17.82</td>
</tr>
<tr>
<td>Lecture hall</td>
<td>22</td>
<td>-0.25</td>
<td>3.73</td>
</tr>
</tbody>
</table>

Table 2: T^2 testing results

<table>
<thead>
<tr>
<th></th>
<th>F - statistic (α)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entrance hall</td>
<td>0.235</td>
</tr>
<tr>
<td>Relaxation hall</td>
<td>0.054</td>
</tr>
<tr>
<td>Lecture hall</td>
<td>0.056</td>
</tr>
</tbody>
</table>

α: the upper sided α point in F distribution
Fig. 5 Distribution of Answers - Lecture Hall (by Hue in L′a′b′ System). Each vertical line means an answered color and the number of answers is expressed by the height.

interior. Real interiors have sophisticated color composition consisted of uncountable nuances and it is practically impossible to be done with accuracy without computer, for example, if we merely look at the interior or if we see an image of it.

2) Having the mean color is a starting point to analyze the interior for dark and light balance, spacial orientation and evaluation of the color accents.

5. Conclusion
A simple method of determining the color impression of interior in public welfare buildings is described. It is shown that the new parameter "mean color" is related to the human impressions from the rooms in the welfare building. Consequently, the mean color is capable for approximating the atmosphere of rooms for public welfare buildings, where it has the most adequate application.

6. Acknowledgment
The authors highly acknowledge the participation of Assoc. Prof. Akihiro Yoshida (Tohoku Institute of Technology) and Douglas Yugi Kawano (Berkeley, Univ. of California) in the discussions concerning the mean color parameter, substantial for this research.

References
3) Wilson, R. F.: Colour and light at work, Seven oaks Press LTD, 1953

Notes
n1) Designed by International Development Consultants Co., Ltd. Kusuyama Sekkei and Kuniaki Ito.
n2) During the process of taking the video footages the camera was in automatic mode; it means that the adjustments of the aperture were automatic, following the lightness of the objects, something that is common for the human eye.

Appendix
Interior colors, colors of the floors, walls and ceilings, in fourteen welfare facilities in Miyagi prefecture were surveyed. The color of each interior part was matched against the JIS Z8723 color chart. The Fig.A1 and Fig.A2 show the identified colors in terms of Hue-Saturation and Hue-Lightness, respectively.

It is obvious from the measured color distribution that the color coordinates in welfare facilities have tendencies to be higher in lightness and lower in saturation. That means this type of buildings has moderate (soft, warm, calm) interior colors.

Fig. A1 Distribution of interior colors by their Hue and Saturation values (marks mean individual buildings)

Fig. A2 Distribution of interior colors by their Hue and Lightness values (marks mean individual buildings)