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# Using a Digital Camera to Identify Colors in Urban Environments

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**Abstract.** *A method for identifying colors in urban environments using a digital camera was established. Color analysis of images was performed using the CIELAB color space. The color coordinates were used to produce a color chart of prevailing colors in the area, which was later used to design a textile pattern. Color samples were in good agreement with the perceived colors of the surroundings. Neutral colors in gray tones predominate in the majority of the city of Ljubljana, Slovenia; nevertheless, there are also bright colors, notably green, yellow, and beige. The method described is fast and reliable enough to identify colors in urban environments. However, the analysis of a large number of photographs is needed to ensure objective results. To obtain reliable results for measured color values, it is necessary to exactly define the conditions under which photographs were taken.* © *2011 Society for Imaging Science and Technology.*
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## INTRODUCTION

Light and color are very important for the perception of space and time and, consequently, for movement.[1,2] The appearance of the colors we perceive depends on many factors, such as the surrounding light, distance, and the colors of objects in the vicinity. Color, light, and space are inseparable in the process of color perception. In architecture, in addition to color tone, the type of material, its texture and its gloss play a large role in the emergence of color perception.[3] Recently, six methods for determining perceived colors have been developed and evaluated along with a method for comparing perceived and inherent colors.[4] Imaging science is a useful new tool that makes use of the aesthetic powers of photography to facilitate the introduction of scientific findings to research communities. Images can be captured more easily and quickly using digital photography. Photographs with detailed imaging information may provide critical scientific information.[5–7]

Image capture systems such as digital photography are frequently used in many areas. One use was presented by Brozovic and Knesaurek,[8] who studied artwork reproduction. While their study focused on reproduction, the focus of this study was on capturing environmental colors. A similar approach was used by Gou and Wang,[9] who defined the colors in an urban environment in China to identify dominant colors for use in urban planning, to serve as guides for architects, and to inform the use of new materials and technology. Digital cameras are capable of detecting even small color differences, as has been previously reported using samples that are compared with a spectroradiometer.[10]

The performance and capability of digital cameras, in contrast to conventional cameras using film, were investigated by Tani.[11] Traditional silver-based, environmentally problematic wet chemical processing can be avoided using digital technology. Kwon and Cho[12] discovered that digital cameras provide quality comparable to that of color film with an indisputably higher level of convenience. Kwon also discovered that the best camera settings can be determined through experimental work with selected illumination.

The purpose of this study is to investigate the possibility of using digital photography to identify colors in urban environments. Color characteristics of different city areas in the city of Ljubljana under different weather conditions and illuminations are determined to produce printed color charts that can be used for the design of a special textile pattern.[13] Colorimetric analysis is performed using the CIELAB color space. This method has been previously presented in research of historical stone walls in England,[14] where stone wall segments the size of a spectrophotometer aperture are analyzed. CIELAB can be used to convert colors among color models. It is also device-independent and capable of preserving original color values transferred from one color reproduction device to another.[15]

## MATERIALS AND METHODS

### *Photography*

A visual analysis of the city identified different typical colors in various areas; therefore, the city of Ljubljana was divided into four zones: (1) the city center, (2) the old historical town, (3) the shopping area, and (4) the street area. Over 2000 photographs were taken of the city during a period from October to December under different weather conditions. All images were taken with a Fujifilm FinePix® S5600 digital camera. Technical image characteristics were as follows: 72 dpi resolution, $2592 \times 1944$ pixel size ($68.58 \times 91.44$ cm), JPEG image format and RGB color model.

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**Table I.** CIELAB coordinates and color chart of prevailing colors for zone 1—city center.

| Sunny | | | | Cloudy | | | |
|---|---|---|---|---|---|---|---|
| L* | a* | b* | color | L* | a* | b* | color |
| 17 | 3 | 6 | | 7 | 0 | −3 | |
| 67 | 1 | 24 | | 53 | −1 | 4 | |
| 27 | 6 | 5 | | 42 | 2 | 5 | |
| 80 | −6 | 18 | | 46 | −8 | 9 | |
| 13 | −2 | −1 | | 5 | 2 | 1 | |
| 62 | 5 | 12 | | 58 | 9 | 6 | |
| 81 | 0 | 15 | | 67 | 0 | 7 | |
| 75 | 1 | 8 | | 53 | 0 | −7 | |
| 20 | −3 | −2 | | 39 | −3 | 3 | |
| 54 | −1 | 14 | | 24 | 3 | −2 | |
| 40 | 0 | 6 | | 18 | −1 | −4 | |
| 81 | −3 | −1 | | 55 | 0 | −10 | |

**Table II.** CIELAB coordinates and color chart of prevailing colors for zone 2—old town.

| Sunny | | | | Cloudy | | | |
|---|---|---|---|---|---|---|---|
| L* | a* | b* | color | L* | a* | b* | color |
| 81 | 0 | 10 | | 73 | −1 | 8 | |
| 69 | 1 | 20 | | 58 | 1 | 5 | |
| 68 | −5 | 28 | | 56 | −6 | −3 | |
| 62 | 6 | 11 | | 19 | 3 | −4 | |
| 89 | −3 | 4 | | 61 | −1 | −2 | |
| 85 | −4 | 6 | | 27 | 0 | −8 | |
| 91 | 3 | 23 | | 53 | 3 | 14 | |
| 84 | 0 | 20 | | 65 | −2 | 12 | |
| 73 | 2 | 15 | | 58 | 0 | 2 | |
| 44 | −11 | 10 | | 35 | −8 | 0 | |
| 89 | 5 | 31 | | 34 | 3 | 12 | |
| 84 | 1 | 16 | | 51 | −1 | −7 | |

### *Color Analysis*

The colors of objects up to 4 m from the ground were determined, and the colors of roofs, greenery, people, cars, and deep shaded places were excluded from the analysis. The typical or prevailing colors of objects analyzed were identified. CIELAB coordinates of those colors were obtained using Adobe PHOTOSHOP software. Microsoft excel software was used to process the data. On the basis of the CIELAB values, color charts with samples of the prevailing colors were printed with a Canon W8400 ImagePROGRAF® printer on semigloss paper.

## RESULTS AND DISCUSSION

For each of the four city zones, typical colors were determined according to the described procedure. In Table I, the CIELAB values of typical colors in zone 1, the city center, are presented. The results are shown as color samples, which were later used to present the colors of selected city areas and to design a special textile pattern for the urban environment. The lightness values of prevailing colors in zone 1 ranged from $L^* = 13$–$81$ for sunny and $L^* = 5$–$67$ for cloudy weather conditions, with average values of $L^* = 51$ for sunny and $L^* = 39$ for cloudy weather conditions. This confirms the expectation that higher lightness values would be measured under conditions of higher illumination. The chroma of samples representing the objects in zone 1 ranged from 2–24 for sunny and 2–12 for cloudy conditions. Low values of chroma indicate the domination of neutral, unsaturated colors, which are even more evident under cloudy conditions. The average values of characteristic a* and b* for zone 1 were calculated to be $a^* = 0$ and $b^* = 9$ for sunny and $a^* = 0$ and $b^* = 1$ for cloudy weather conditions. However, the distribution of colored samples in this zone is very wide, thus making it difficult to identify only a few prevailing colors.

Table II presents the prevailing colors and their CIELAB values for zone 2, the old historical town. Lightness values in zone 2 ranged from $L^* = 44$–$91$ for sunny and $L^* = 19$–$73$ for cloudy conditions, with average values of $L^* = 77$ for sunny and $L^* = 49$ for cloudy conditions. The average values of a* and b* for zone 2 were calculated to be $a^* = 0$ and $b^* = 16$ for sunny and $a^* = -1$ and $b^* = 2$ for cloudy weather conditions. These results again confirm that, under conditions of higher illumination, higher lightness values are observed. The colors in this city area are slightly more vivid, especially in sunny weather; the chroma values of samples representing the objects in zone 2 ranged from 5–31 for sunny and 2–14 for cloudy conditions. Table III presents the prevailing colors and their CIELAB coordinates for zone 3, the shopping area. Lightness values ranged from $L^* = 12$–$94$ for sunny and $L^* = 8$–$76$ for cloudy conditions, with average values of $L^* = 64$ for sunny and $L^* = 46$ for cloudy conditions. The chroma of color samples representing the colors of the objects in zone 3 ranged from 5–82 for sunny and 4–64 for cloudy conditions. The sample in the red–yellow region is an example of advertising activity on building walls. The average values of a* and b* for zone 3 were calculated to be $a^* = 5$ and $b^* = 16$ for sunny and $a^* = 6$ and $b^* = 6$ for cloudy conditions. Colors in this area are mostly achromatic and unsaturated. Nevertheless, in this city area, there are also some objects in vivid red, blue, and yellow saturated colors.

Table IV presents the prevailing colors and their CIELAB coordinates for zone 4, the street area. Lightness ranged from $L^* = 39$–$97$ for sunny conditions and $L^* = 36$–$85$ for cloudy conditions, with average values of $L^* = 69$ for sunny and $L^* = 63$ for cloudy conditions. Again, higher lightness values were observed under conditions with higher illumination. The average values of a* and b* for zone 4 were calculated to be $a^* = -1$ and $b^* = 5$ for sunny and $a^* = 0$ and $b^* = -4$ for cloudy conditions. The

**Table III.** CIELAB coordinates and color chart of prevailing colors for zone 3—the shopping area.

| Sunny | | | | Cloudy | | | |
|---|---|---|---|---|---|---|---|
| L* | a* | b* | color | L* | a* | b* | color |
| 86 | −1 | 6 | | 76 | −1 | 6 | |
| 51 | −8 | −32 | | 35 | 3 | −40 | |
| 73 | −10 | 5 | | 64 | −9 | −1 | |
| 80 | −8 | 11 | | 38 | −7 | −5 | |
| 12 | −2 | −5 | | 8 | −1 | −4 | |
| 94 | −1 | 82 | | 52 | 1 | 51 | |
| 54 | 63 | 46 | | 46 | 54 | 34 | |

**Table IV.** CIELAB coordinates and color chart of prevailing colors for zone 4—the street area.

| Sunny | | | | Cloudy | | | |
|---|---|---|---|---|---|---|---|
| L* | a* | b* | color | L* | a* | b* | color |
| 97 | −9 | 35 | | 69 | 0 | 20 | |
| 64 | 9 | 9 | | 67 | 6 | 2 | |
| 78 | −4 | 0 | | 78 | −2 | −5 | |
| 39 | −3 | −2 | | 36 | 0 | −17 | |
| 50 | 0 | −3 | | 38 | −1 | −8 | |
| 61 | −1 | −2 | | 59 | 0 | −7 | |
| 78 | −1 | 0 | | 60 | −1 | −8 | |
| 82 | −2 | 4 | | 69 | 0 | −6 | |
| 42 | 0 | 5 | | 61 | 1 | −4 | |
| 75 | 1 | 6 | | 67 | 0 | −5 | |
| 96 | −1 | 2 | | 85 | −1 | −5 | |

chroma of the samples representing the colors of objects in zone 4 ranged from 1–36 for sunny and 4–20 for cloudy conditions. Very low values of chroma indicate the domination of neutral, unsaturated colors, which are especially evident under cloudy conditions. Table V presents a comparison of lightness and chroma values for different city areas under sunny and cloudy conditions as well as CIELAB color differences arising from the different weather conditions. The average values of lightness and chroma for each of the four city zones are presented in Figures 1 and 2. CIELAB coordinates showed that measured values change with illumination conditions. Although the deviations observed are not negligible, the weather and the time of day do not have a major influence on the determination of prevailing colors. Such results are very likely to be a consequence of the fact that the differences between the colors observed in a specific area are much larger than the changes in color due to changes in observation conditions.

In the process of objectively determining color, the selected method and observational conditions play an important role. It is clear that weather and lighting conditions affect the detection and measurement of color and, consequently, its numerical description. Nevertheless, it should be noted that color constancy plays an important role in the perception of the colors of objects illuminated with natural light. The human visual system is able to adapt to changes in the spectral composition of light; therefore, color can look more or less constant despite changes in the measured reflectivity of the observed surface. The range of nuances and surface characteristics in urban areas is so great that a minor modification in light normally does not result in a new shade and is therefore less important in the identification of dominant colors.

CIELAB coordinates of the prevailing colors in Ljubljana obtained using the method described above were used to design a color chart that consists of a collection of color samples compiled using electrophotography. This technology was chosen because, while printing with ink jet technology is fast, the print on paper takes 4–5 days to become fully stable.[16] The colors collected in the color charts were visually in agreement with the different areas observed and reflected the actual appearances of the surroundings. Three of the suggested colors were used for the construction of a camouflage pattern for urban environments.[13]

The purpose of this study was to establish a method for defining the dominant colors in an environment using a digital camera. The method presented is useful and relatively simple, but it has limitations that need to be considered. Digital photography presents a simple method for providing an objective description of the environment, including its colors. However, such a description of colors does not take into account the fact that color is a psychological experience caused by light reflecting from the colored surface and entering the human eye. The observer plays an important part in the identification of typical or prevailing colors. Therefore, to achieve reliable and unbiased results, a very large number of samples, i.e., photographs, must be analyzed. Also, to establish exact and objective color values for the objects in a specified area, it is necessary to precisely define the observational conditions, the distance from which the photographs are taken and camera characteristics. The analysis of the impact of individual factors, such as light, observation distance, surface texture and reflectivity, should be based on well-defined color values obtained with spectroradiometric measurements, for example. Using a spectroradiometer, which enables color measurements from a distance, more accurate measurements can be obtained with a smaller observed surface. Moreover, it would be helpful to use color samples, such as Munsell or Natural Color System samples, to allow for an objective evaluation of the colored areas. Certain limitations for such an approach arise from the fact that some areas are remote and hard to access.

## CONCLUSIONS

The prevailing colors of an urban environment were described using a simple method based on digital

**Table V.** Comparison of lightness (L*) and chroma (C*) values for different city zones under sunny and cloudy conditions.

| | Zone 1 | | Zone 2 | | Zone 3 | | Zone 4 | |
|---|---|---|---|---|---|---|---|---|
| | Sunny | Cloudy | Sunny | Cloudy | Sunny | Cloudy | Sunny | Cloudy |
| $L^*_{min}$ | 13 | 5 | 44 | 19 | 12 | 8 | 39 | 36 |
| $L^*_{max}$ | 81 | 67 | 91 | 73 | 94 | 76 | 97 | 85 |
| $L^*_{av}$ | 51 | 39 | 77 | 49 | 64 | 46 | 69 | 63 |
| $C^*_{av}$ | 9 | 1 | 16 | 2 | 17 | 9 | 5 | 4 |
| $a^*_{av}$ | 0 | 0 | 0 | −1 | 5 | 6 | −1 | 0 |
| $b^*_{av}$ | 9 | 1 | 16 | 2 | 16 | 6 | 5 | −4 |
| $\Delta E^*_{ab}$ | 14 | | 31 | | 21 | | 11 | |

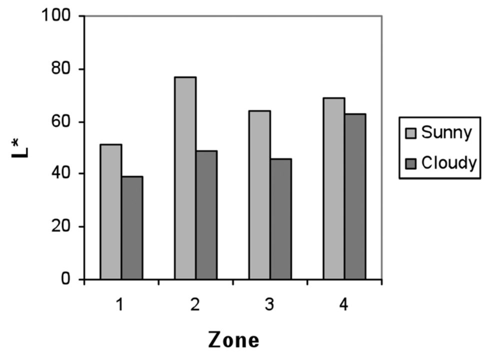


Figure 1. Average values of lightness (L*) calculated under sunny and cloudy conditions for different city zones.

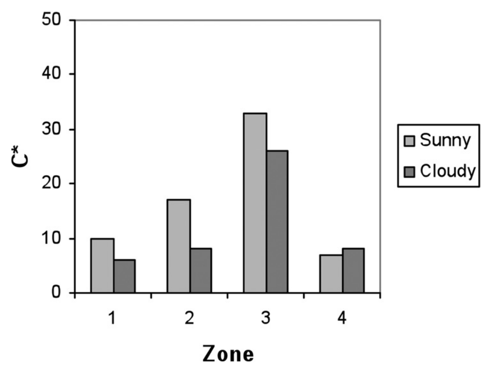


Figure 2. Average values of chroma (C*) calculated under sunny and cloudy conditions for different city zones.

photography. Nevertheless, the analysis of a large sample base, i.e., photographs, was crucial to ensure objective results. The method described was fast and reliable and could be used for designing a collection of color samples using electrophotography. To establish exact color values for objects, observational conditions and the distance the photographs were taken from must be precisely defined.

Color analysis of the city of Ljubljana showed that the city could be divided into at least four different areas according to characteristic colors. Neutral colors in gray tones prevail in the majority of the city, but there were also bright colors, notably green, yellow, and beige.

Weather and the illumination conditions had only a minor influence on the definition of the prevailing colors of the surroundings. Sunny weather conditions, with higher illumination, led to higher lightness values but had less influence on chroma values, which were generally also higher at higher illuminations.

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