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Image color-based preset light matching algorithm for an electric vitrine

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Abstract

The study proposes an algorithm for matching light presets in recent advanced light systems. It aims to provide users with a more accurate and intuitive way to navigate proper lighting based on the color characteristics of the displayed object. The algorithm is applied to an electric vitrine equipped with 15 RGB LEDs, and a pool of 25 light presets created through a workshop with experienced light designers. The algorithm matches the light presets to a user-taken photograph by considering the hue similarities between the objects in the image and the light preset. The algorithm solution deliberately provides three alternatives: the best chromatic light color, the most optimal standard illuminant, and the best color spectrum. We expect the algorithm to be applied to different contexts, where light needs to be strategically tuned by being aware of the context characteristics.

Introduction

Lighting is a critical factor in recognition of materials and objects. The characteristics of lighting, such as color, light distribution, brightness, and contrast, remarkably influence how objects are perceived and interpreted. Proper lighting can bring out an object's true colors and qualities, enhancing its appearance and making it easier to recognize [1]. Conversely, poor lighting choices can distort the colors and obscure the true appearance of an object, making it less appealing and challenging to identify. However, although the critical role lighting plays in object recognition, many users must give proper consideration to lighting or have limited control over it.

The development of smart lighting system technology has made it possible for users to control and adjust the lighting to suit their needs and preferences [2]. In addition, the smartphone applications, such as the Philips Hue app, provide users with a convenient and intuitive way to modify the color and brightness of lighting. However, despite the diverse options of the applications, users still need help with choosing the appropriate lighting based on their context. Subsequently, recent smart lighting systems have offered lighting presets through their interfaces, making it easier for users to select the desired lighting as shown in Figure 1. Still, there remains a need for other technologies to assist users in navigating the optimal lighting [3], ensuring a more satisfying and emotionally triggering lighting experience.

This study focuses on an electronic vitrine designed to showcase precious items. The vitrine is equipped with a strip of color-changeable RGB LED lights, allowing users to select the lighting that best highlights their displayed items. To enhance this experience, we propose an algorithm that analyzes the image of the displayed object and provides recommendations to users. We aim to offer users a more intuitive and affective approach to choosing a light for users' displaying their valuable items.

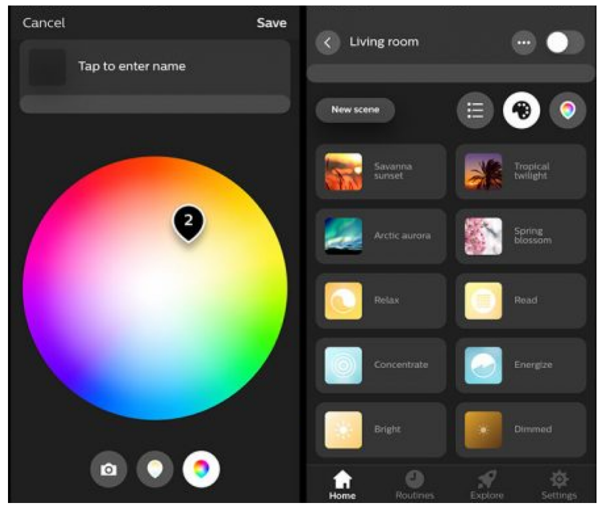

Figure 1. *Philips Hue lighting control interface. The user can custom color for the light (left) or select a preset option (right).*

The Electric Vitrine

In this study, we employed a prototype electric vitrine to apply the algorithm, and LG Electronics planned to launch the first model soon. The vitrine features three transparent sides, providing a clear view of the stored collections, such as shoes and bags. The vitrine has two lights: a main LED with a color temperature of 4,000K in the center and a strip of 15 LEDs that can change color. The algorithm focuses on adjusting the color of the strip light installed at the back of the vitrine. Figure 2 illustrates the

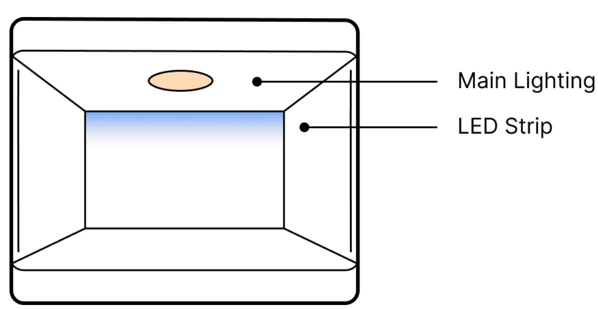

Figure 2. *The design and lighting arrangement of the electric vitrine used in the study.*

electric vitrine and the lighting distribution.

Workshop: Finding the Lighting Presets

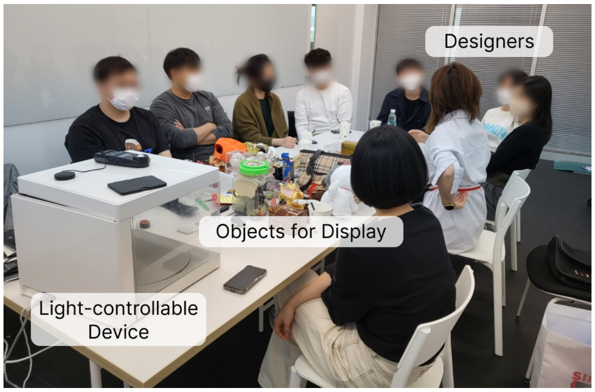

Figure 3. *The expert workshop for designing the lighting presets.*

In this study, we aim to recommend the most suitable lighting for items displayed in an electronic vitrine. However, without considering visual aesthetics or user preferences, the algorithm may suggest colors that are not appropriate for lighting. We have established a set of aesthetically pleasing presets through expert workshops to mitigate this. The algorithm intends to select the most appropriate preset, ensuring that the recommended lighting solution is aesthetically pleasing, even if it may not match the object's color.

A total of nine designers participated in the lighting design workshop. The participants were professionals in lighting design or UX design. The workshop proceeded using a prototype of the vitrine equipped with adjustable lighting and various objects in it. During the workshop, every object was placed in the center, and light color was carefully selected by comparing the prototype's main light in both on and off state.

The workshop resulted in 25 preset selections, including four standard illuminants, fifteen single-colored presets, and six multi-colored presets. The standard illuminants were chosen to cover a CCT range of 3000 K to 8000 K, while maintaining a delta uv value of less than 0.005. The single-colored presets were selected based on a range of hues and saturations. The 15 LED lights were divided into five groups to form the multi-colored presets.

Recommendation Algorithm

Our algorithm guides users to place the object at the center of the vitrine and take a picture following specified instructions, including the angle and the proportion. The surrounding environment may influence the object's color in the image. Hence, to minimize such effects, the main light is directed to be turned on. This light source comprises 4000K LEDs of uniform brightness, allowing the object to be captured in a relatively consistent lighting environment.

The algorithm converts the color information of all input pixels to a Lab value and first determines the white point of the object. Based on the L value, the brightest 5% of pixels, are extracted. Then the algorithm calculate the average color of extracted pixels. This average color is then used to calculate the color temperature value. Finally, the algorithm recommends the standard illuminant preset with the closest color temperature to the derived color temperature value.

Afterward, the algorithm amplifies the number of pixels with a saturation of 35 or higher by multiplying their number by 30, as these highly saturated colors strongly attract human attention. Then, by clustering the collected pixels into 12 colors through the k-means algorithm, the algorithm creates a color palette associated with the object's color. The most dominant color of the palette was decisive for the order of the recommendation of single-colored presets. In the algorithm, the color value of the vitrine wall surface captured with each preset turned on is prepopulated into the same environment as the guided photography. Finally, the algorithm calculates the Euclidean distance between the dominant key color of the object image and the color value of each preset. It ranks the presets from the closest to the farthest.

In order to recommend a multi-color light preset, the algorithm considers the three most dominant colors in the color palette. The tone of the recommended preset will primarily follow the dominant key color. For example, a bluish preset is derived when the blue object is displayed. However, if the distances

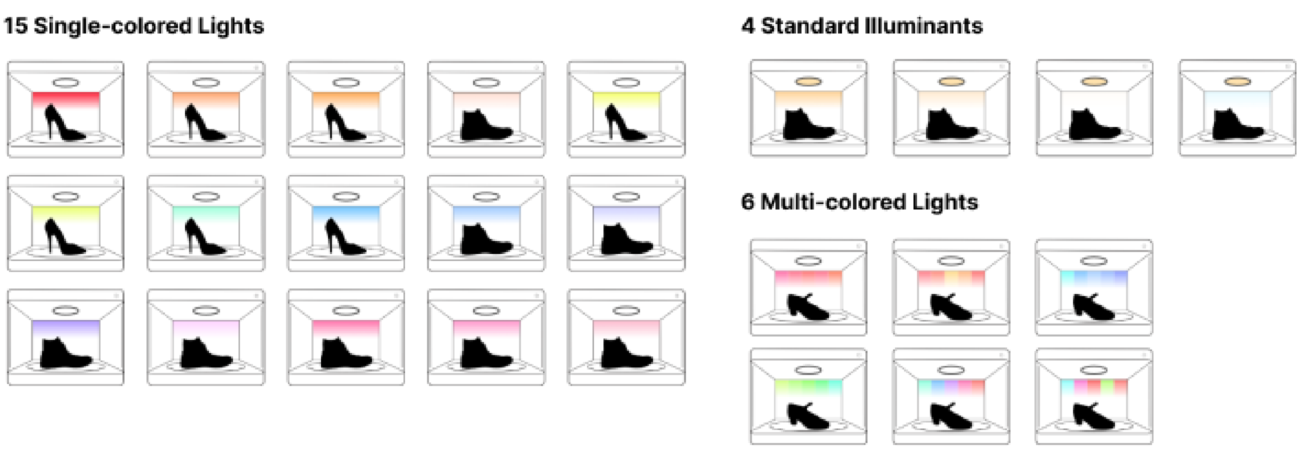

Figure 4. *25 lighting presets generated by the workshop It consists of 15 single-color lights, 4 standard illuminants, and 6 multi-colored lights.*

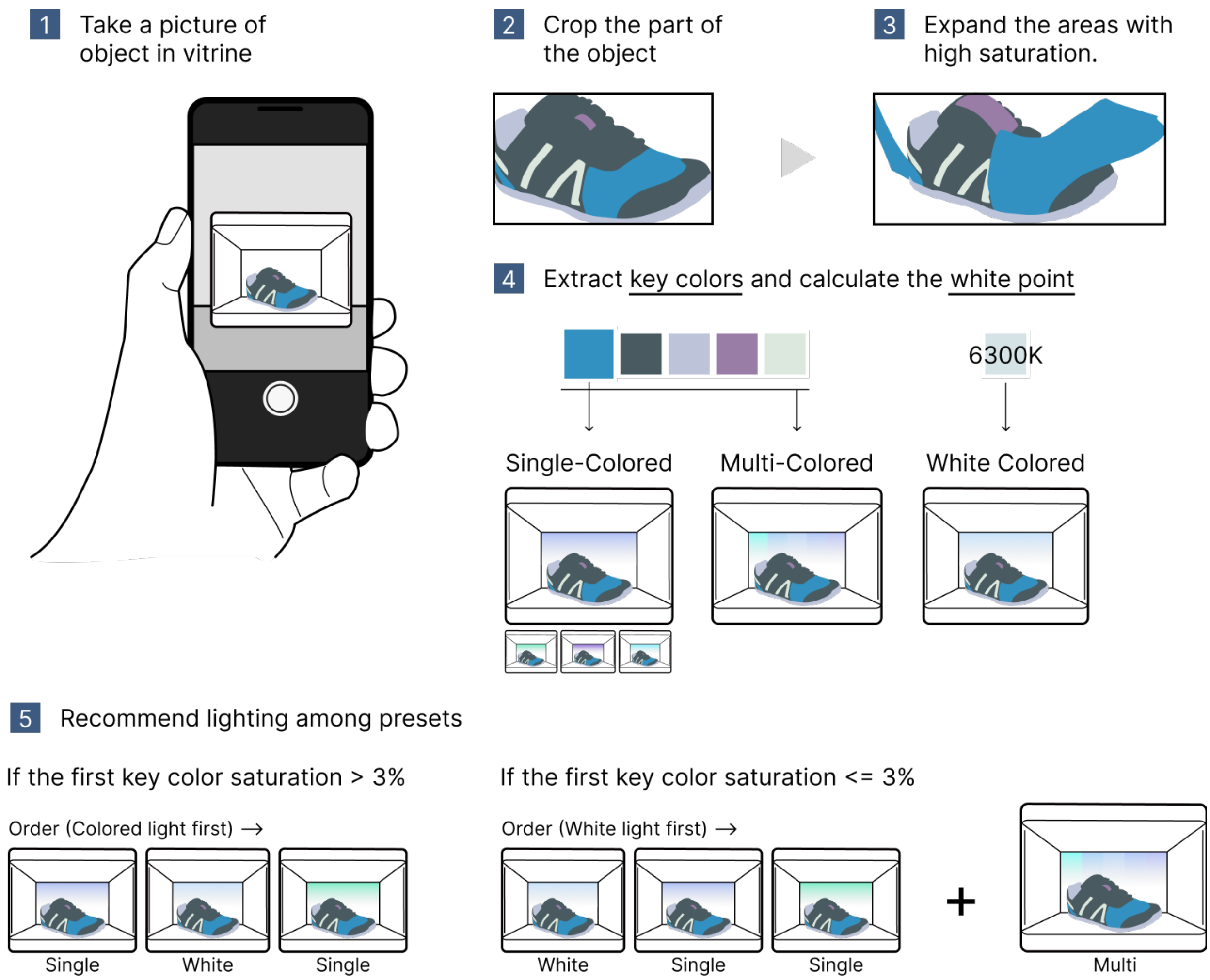

Figure 5. *The flow of lighting recommendation algorithm.*

between the three colors of the palette are widely separated, the algorithm recognizes the object as having a mixture of different colors. As a result, the algorithm will recommend presets with various colors instead of presets composed of colors with similar tones.

After extracting the optimal lighting options, the algorithm proposes them to the user. The algorithm proposes multi-colored presets separately from other presets since they consist of a sequence of colors, unlike other presets. The single-colored presets and standard illumination are presented within a series, and this order depends on the saturation of the dominant color. Since the color extractor used in this algorithm reflects the human cognition system, colors with high saturation have a higher priority than those with low saturation. Nevertheless, if the saturation value of the first extracted color is less than 35, the object is judged to be achromatic. If the object is colored, the single-colored light preset with the highest priority is first proposed. On the other hand, if the object is achromatic, the algorithm presents the standard illuminant preset first and then different chromatic lighting presets in priority.

Results and Discussion

Figure 5 shows the image of the cropped object presented to the algorithm for testing, the color palette of the image calculated by the algorithm, and the corresponding light is recommended.

In this study, we present an algorithm recommending the best-matching light preset for the items displayed in an electronic vitrine. This recommendation system provides an effortless and automated solution for novice users to find optimal lighting. Unlike conventional smart lighting services that offer preset options, our algorithm offers recommendations based on the color analysis of the item's image taken by the user. The manufacturer can also collect crowdsourced photos of the user behavior to improve the system. Our image color-based approach has the potential to inspire creative applications for various spaces and purposes beyond the use of the vitrine.

Although the current study was limited to an electric vitrine, an automatic light match is increasingly demanded for various purposes. As a preliminary study, we focused on the image color characteristics of displayed objects as the cue to search for the optimal light preset. Any signal or input from the context should trigger the matching solution to enhance the affective quality of the light environment.

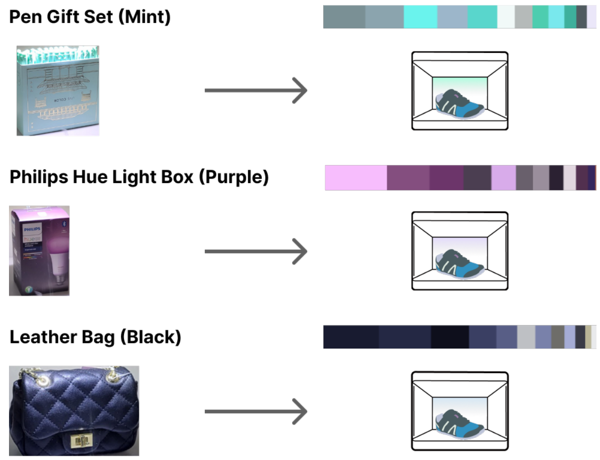

Figure 6. *Examples of the actual use of algorithm. It shows the cropped input image, the calculated color palette, and the top recommended lighting preset.*

Furthermore, the algorithm identifies the object's color and offers the most similar lighting preset to the user. This results in a favorable recommendation of lighting that complements the object so that well renders the color of the object. However, the choice of lighting may vary based on the user's preferences, and there may be instances where a color that deviates significantly from the object's color appears harmonious. Further research is required to determine more possible combinations of color and lighting.

Conclusion

In this paper, we developed an algorithm recommending the best light preset for a displayed object in an electric vitrine. First, the algorithm analyzes the color characteristics of the object contained in the image taken by the user. After that, it determines the optimal light preset based on the object's extracted color palette and white point. By combining the user's taking a picture with the smart lighting system, the proposed algorithm provides an easy and convenient way for novice users to find the optimal light for the displayed object. Furthermore, this color-based approach not only provides a solution for electric vitrines but also has the potential to inspire creative user scenarios for various spaces and purposes. Hence, it can meaningfully contribute to the smart lighting field.

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