https://doi.org/10.2352/EI.2022.34.15.COLOR-374

New Image Processing Algorithm towards More Realistic Expression on Hair Coloring

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Abstract

Hair dye market provides hair dye products and virtual hair coloring services to customers. The virtual hair coloring service provides consumers a more realistic user experience by checking its outcome color in advance whether the hair color will suit them or not before consumers dye their hair. However, this rendering service malfunctions to check the final hair color of the real world, because current digital color changing methods are rooted in computational methods like layering through proportional mixture or replacing color values. On this account, we propose a new color rendering processing method for human hair. The new algorithm contains a lookup table, made of measured color values in terms of CIELab. Based on the lookup table, the hair color estimation model determines the brightness of the hair area for the input image, calls the color value adjusted from the lookup table according to the determined hair brightness, and reflects both brightness value and adjusted color value to the final rendering. Since the lookup table was created to reflect the actual hair dye result data, this new image processing shows a better hair color rendering result which close to the real hair dye coloring.

Introduction

Personalization in customer experience is regarded as important by all industries. Beauty industry is no exception. The beauty industry encompassing skin care, color cosmetics, hair care, fragrance, and personal care follows *a silent knowledge:* The personal color rule has become commonplace. Accordingly, *Personal color* means finding the best hue and tone harmony on each person and especially there are three dominant colors for determining personal color: It is skin color, iris color of our eyes, and hair color. As well, hair dyeing has been the most effective method of changing or improving an individual's impression. And what's more, due to the Covid-19, as people are encouraged to stay indoors or wear masks, hair color becomes the most note-worthy color, ever. Covid-19 has changed our work and our lives seriously, on one hand, it created a digital transformation boom.

On the technological side, *Augmented* Reality (AR) technology is verifying its role and effectiveness above many studies in various fields. AR has been attracted researchers' attention because of its ability to allow users to be engaged in their experience and potential in making the users more active, effective, and meaningful participation [1], [2], [3].

Hair dye market also adopted AR technology to give consumers a more realistic experience on their sales funnel, a customer journey. Figure 1 is the most famous AR service application on the hair dye market in 2021. This application provides vivid hair coloring rendered images. Since this service supports a various color range from mild (close to original hair color) to vivid color rendering, consumers are able to try various colors on their hair.

There are also other services. Figure 2 shows the results of a virtual service that simulates the hair color for selected hair dye products. This service provides hair coloring simulation on image or video, which makes consumers visualize the color of hair dye product before they buy, just like the name of the service. However, the rendered hair colors are quite ridiculous for most base hair cases.

On the entertainment aspect, Figure 1 is a brilliant service. If you find the color you dreamed of, you can accomplish it with an aid of a hair stylist at Salon. However, what about Figure 2, where the purpose of promoting self-dyeing is to promote, and the accuracy of image rendering results is important for product promotion? It seems to work well at first glance, but there are defects. We have heuristic knowledge that dyeing hair has different results depending on the base brightness of the hair. Depending on the brightness of the base color, the final color should be different even if the same dye product. However, the virtual service shows steady hair coloring results on various hair types. Also, in Figure 2, the service detected error in all 12 cases and the service simply says 'shade not recommended' when these unrealistic rendering results come out. From this result, we can infer AR service has not been sophisticatedly implementing hair coloring results of dye products, and also, this service does not handle subtle differences between dye colors. Considering the purpose of the AR coloring service is to provide a more realistic user experience by checking in advance whether the color will suit them before consumers actually dye their hair, the rendering does not fulfill the original purpose of the AR service.

This may be because the current image processing method of hair dyeing simply uses a method of adjusting opacity [6] or merely replacing the hue and saturation value with the target color [7]. In reality, permanent hair dyeing is not simply a process of changing the opacity or replacing the color value: Hair coloring process like hair bleaching and subtractive coloring on Salon is a series of a chemical reactions. Then, how can we reproduce the result of the permanent hair dyeing in reality to the digital?

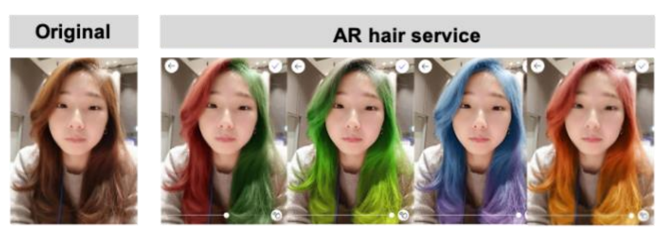

Figure 1. *Hair coloring AR service of MakeupPlus, offered by Meitu Eve Company.*

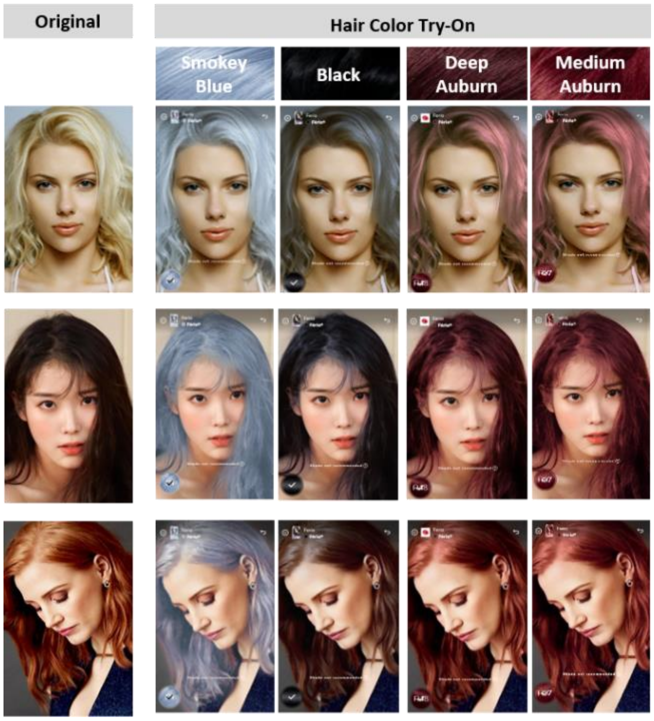

Figure 2. Hair coloring AR service of L'Oréal, named 'Try on any color before buying'.

Objective

Current hair coloring AR services and algorithms from open source change the color simply calculate color values through computational methods, such as adjusting the opacity or shifting hue and saturation linearly. The limitation of these methods is that the difference in the base hair brightness is not sophistically considered.

The objective of this study is to propose a new image processing method that considers the permanent hair dyeing mechanism for a more realistic hair coloring result. Figure 3 shows a result of red dye hair coloring with four different hair tresses. The result shows that although the same red hair dye is used, each hair tress has a different outcome depending on the base hair brightness. We propose a coloring image processing method that roots in the difference between brightness levels. To consider the brightness of hair, we added a lookup table to our algorithm, and in this paper, we want to explain how the lookup table should be made for more realistic hair coloring in the digital world.

***Figure 3.** Actual dyeing results of various base hair with red hair dye. Depending on the brightness of the base color, the final color is different even if the same dye is used.*

Method

Overall Process

The process follows a sequence of Figure 4. First, white balancing and hair area segmentation is needed. For the image pre-processing, deep learning models were used. Especially, for image segmentation, the algorithm employs the ResNet model [8], a deep-learning-based feature detection to identify hair regions.

After pre-processing, the image is employed by three modules on the hair color estimation stage. the algorithm follows three steps. Module 1 determines the brightness of the hair area for the input image refer to the lookup table. Module 2 reads the color range and location of the adjusted target dye according to the detected brightness of the hair. The last, module 3 renders the final color on the segmented hair area by replacing them as the adjusted color value. To sum up, the algorithm determines the brightness of the hair area for the input image, calls the adjusted color value from the lookup table refer to the determined hair brightness intensity, and reflects both brightness value and adjusted color value to the final rendering. And all this process is rooted in the lookup table.

Our lookup table is made of a series of measured color data. We considered 'Hello Bubble' hair dye product from Mise En Scene Company as our data sample. Hello Bubble is the most famous hair dye product in Korea for vivid coloring outcomes: It was easy to gather user reviews to check the implementation of rendering color. The following section is about the lookup table formation.

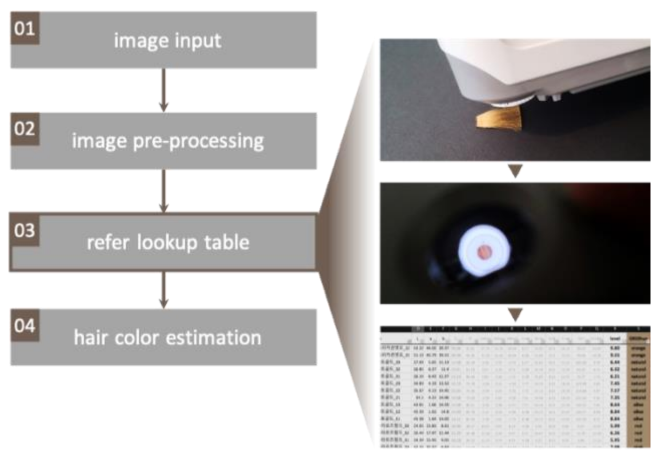

***Figure 4.** Brief of image processing algorithm for hair coloring AR service. The lookup table contains L*, a*, b* measured data to judge the brightness of hair for the input image.*

Lookup Table

As Figure 3 showed, the same hair dye functions differently depending on the base hair, especially the brightness level of base hair. We secured the range of base hair brightness levels into four-level, which encompass black hair and three level of bleached hair. So, we applied one hair dye on four different brightness level hair tress each to cover the range of base hair. Next, for each hair tress, we measured its color data, in terms of CIELab. L*, a*, and b* value were measured by a Spectrophotometer (CM2600d, Minolta Co.) in SCI mode. To sum up, one hair dye product holds four pairs of L*, a*, and b* color data for different hair brightness levels. For every hair dye product recording its outcome color depends on the base hair and this data is accumulated on the lookup table.

Since we only proceed whit this data collection for four types of the brightness of base hair, linear interpolation was used to cover the full range of hair brightness [9]. Figure 5 is a graph of the measured value of bleached hair. The colored dots represent the bleached intensity of black hair. Based on this measured data, we executed linear interpolation for hair brightness and the outcome color of hair dye applied.

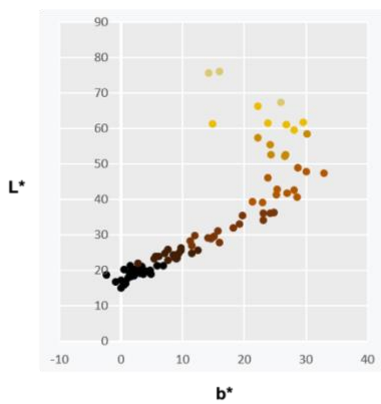

*Figure 5. A graph of measured L*and b* value for bleached human hair.*

Result

Hair Brightness Detection

Figure 6 shows the result of hair brightness detection. For two sample images, L*, a*, and b* values were measured after white balancing and image segmentation are applied. In the left sample image with dark hair, the brightness level is detected as 3.68, which means no bleaching. In the right sample image with ash hair, the brightness level is detected as 8.66, which corresponds to the intensity of bleaching more than one time.

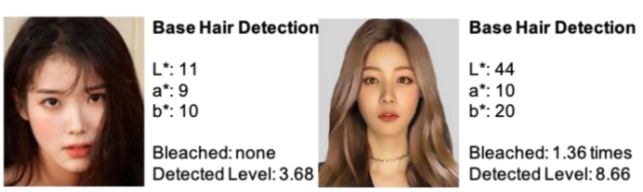

Figure 6. Result of hair brightness detection.

Hair Color Rendering

When the user applies the target hair dye on the image, the final rendering shows adjusted hair color based on the brightness of the user image, which is now close to the real hair dyeing result. Figure 7 is a result of the final rendered outcome sample images for eight hair dyes. When the original hair is medium brightness, hair dyes, in reality, works vividly and this occurrence is applied to Figure 7. This happens to be real because the lookup table is based on the actual measured data of hair coloring outcome.

Figure 7. A part of the final rendered outcome for hair level 8.66 image sample.

Discussion

Algorithm Performance

Currently, hair dyes from *Feria series of L'Oréal Company* and *Creamy Bubble series of Liese Company* also provide virtual hair coloring services each on market. Our algorithm has been verified the correctness of rendered outcomes compared to the actual hair coloring result. In a way, the performance is quite reasonable, since the algorithm is configured to predict the color from the lookup table that is composed of measured color data. One thing to say is that we tested only for *Hello Bubble hair dye series*; Our future plan is to include a various number of dye products' data to prove our algorithm performance.

Future Work

As well, there are still uncovered areas for our algorithm. We only dealt uncolored hair including black hair and bleached hairs as our base hair type on this project. In the case of red hair of natural, grey hairs of aging, or colored hair like dyed hair and stained hair, all these types possess residual pigment issues and we excluded them as input. At a hair Salon, in the real world, the residual pigment is treated with subtracting coloring method to change its color while the black hair and the bleached (including blond) hair are simply treated with a bleaching method. For this issue, we should check whether our estimation is still correct or not through additional experiments.

Also, we want to proceed with a series of user tests. On the user test, we want to explore the role of realistic models among virtual service. When the web demo development is completed, we look forward to meeting users with the algorithm demonstration to discover the design opportunity.

Conclusion

In this paper, we addressed the current status of hair coloring AR services and their rendering credibility. If the purpose of the service is for amusement, the virtual outcome is acceptable. However, if the purpose of the service is for product promotion and coloring simulation, the rendered outcome needs to be improved to advertise dye performance. To solve this problem, we investigate current digital coloring algorithms and reached a conclusion that simple computational methods are not how hair coloring works in the real world. Since hair coloring is a chemical reaction of pigment directly using computational methods is unsuitable for hair dye coloring simulation. In this context, we propose a new algorithm for more realistic expression on virtual hair coring. To make it possible, we added a lookup table to our image processing. This lookup table is made of measured color data, in terms of CIELab, of each hair dye product. Four different brightness levels of hair were used as base hair and recorded different coloring results depending on the brightness of base hair. We used a linear interpolation method to cover the full range of hair brightness. Referring to the lookup table, our algorithm detects the brightness of the input image, estimates adjusted dye color on hair area, and renders the result. In this paper, we showed 8 rendered images for the base hair whose brightness level is 8.66.

Acknowledgments

This research has been supported by the AMOREPACIFIC CORPORATION.

References

[1] Alam Md, Md Hasan, Intisar Hasnain Faiyaz, Ashikuzzaman Bhuiyan, Sheakh Fahim Ahmmed Joy, and Shitab Mushfiq-ul Islam. "Augmented reality education system in developing countries." Electronic Imaging 2019(2): 183-10, 2019.

[2] Tong, Huilin, Qianwen Wan, Aleksandra Kaszowska, Karen Panetta, Holly A. Taylor, and Sos Agaian. "ARFurniture: augmented reality interior decoration style colorization." Electronic Imaging 2019(2): 175-8, 2019.

[3] Bell, Tyler, and Song Zhang. "Holo Reality: Real-time low-bandwidth 3D range video communications on consumer mobile devices with application to augmented reality." Electronic Imaging 2019(16): 7-5, 2019.

[4] "Virtual Try On", L'Oréal. [Online]. Available: https://www.lorealparisusa.com/virtual-try-on-hair. [Accessed: 28 - Jan - 2022]

[5] "Virtual Color Try-on", Liese. [Online]. Available: https://virtual-cosme.net/sg/liese/. [Accessed: 28 - Jan - 2022]

[6] Tan, Jianchao, Jyh-Ming Lien, and Yotam Gingold. "Decomposing images into layers via RGB-space geometry." ACM Transactions on Graphics (TOG) 36(1): 1-14, 2016.

[7] Bora, Dibya Jyoti, Anil Kumar Gupta, and Fayaz Ahmad Khan. "Comparing the performance of L* A* B* and HSV color spaces with respect to color image segmentation." arXiv preprint arXiv:1506.01472, 2015.

[8] He, Kaiming, Xiangyu Zhang, Shaoqing Ren, and Jian Sun. "Deep residual learning for image recognition." In Proceedings of the IEEE conference on computer vision and pattern recognition, pp.770-778. 2016.

[9] Kim and Suk. "Brightness of Hair based on Natural Hair and Bleached Hair," Korea Society of Color Studies Conference, Seoul, Korea, 2021.

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