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Color Reality Implementation of Human Skin on Display Image

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Moonsun, Cho[1]; Minyoung, Lee[1]; Heemuk, Oh[1, 2]; Jun Bae, Lee[2]; Michael, Binns[1]; Sung-Kyu, Hong[1*]

[1] Department of Chemical and Biochemical Engineering, Dongguk University, 30, Pildong-ro 1-gil, Jung-gu, Seoul 04620, Korea
[2] Cosmax R&I Center, Gyeonggi-do 13486, Korea

**Sung-Kyu, Hong, hsk5457@dongguk.edu*

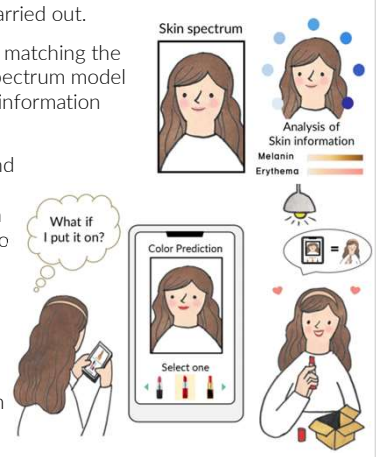
Introduction:

Recently, the online shopping continues to increase due to the influence of the contactless culture from the prolonged COVID-19. As an alternative to this, individual skin condition diagnosis services and non-face-to-face makeup cosmetic color evaluation are emerging. However, it was possible to use an accurate service only by using a specific sensor until now. Therefore, a service that consumers can use conveniently in any environment is required. In this study, three significant steps were carried out.

First, A skin information evaluation method through matching the skin spectrum with the Kubelka-Munk 2-layer skin spectrum model was developed. Moreover, The reliability of this skin information evaluation method was confirmed.

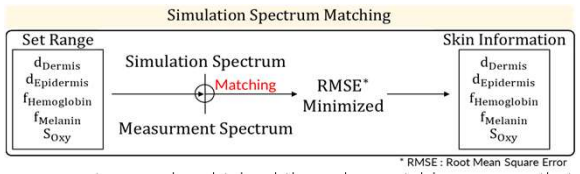
Second, using the optical properties of cosmetics and the advanced Kubelka-Munk 3-layer equation, a cosmetic color spectrum prediction model of the skin was devised. In addition, the accuracy of the predictio model was confirmed by comparing the predicted spectrum and the actual spectrum when cosmetics were applied to the skin.

Third, a color matching model between the actual color and the mobile display color was derived. So, the color of skin applied cosmetic was reproduced on the display.

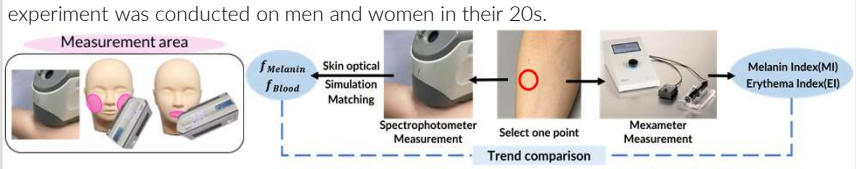


Materials & Methods:

< Evaluation of skin information through skin spectrum matching >

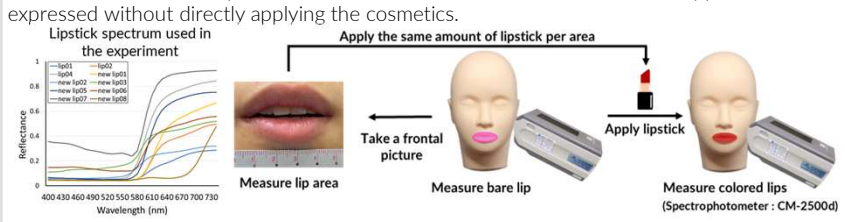


Skin information parameters can be obtained through a matching process that minimizes the error (RMSE) between the existing Kubelka-Munk two-layer skin spectrum model and the actual skin spectrum. To confirm the accuracy of the skin information obtained in this way, an experiment was conducted on men and women in their 20s.



< The cosmetic color spectrum prediction model of the skin using the optical properties of cosmetics >

When light is reflected by the object and enters the eyes, the visual cells sense it and perceive it as color. Therefore, if calculating the behavior of light in the skin and cosmetics obtained the reflection spectrum, the skin color to which the cosmetics are applied can be expressed without directly applying the cosmetics.



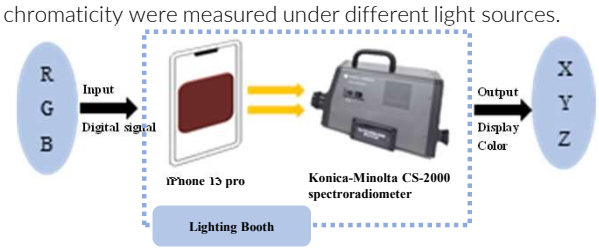
To test the effectiveness of the color prediction simulation formula, the lip spectrum before and after applying to lips was measured and compared with the color prediction results. In the experiment, ten lipsticks of different colors were used. Also, The lip area was calculated, and the same amount was applied per area.

< Measurement for deriving a color matching model >

On the mobile screen, we should be able to check the color when the cosmetics are applied to the human skin. However, due to the color space of the mobile itself, color variations occur in the process of expressing colors through the display, and the lighting of the space, when the user inputs the color into the mobile, color produced on the device can be different from the real color. For this reason, to accurately deliver makeup simulation results to users through mobile devices, color errors that may appear due to display and lighting should be corrected.

- Color characterization of iPhone 13 pro and Light source adaptation

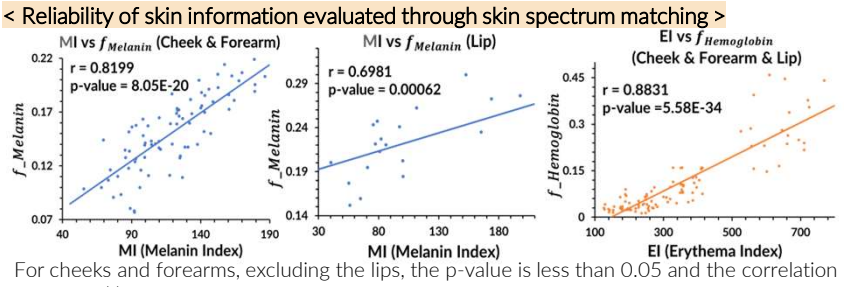
We made the necessary measurements to characterize the color of the iPhone 13 pro display. The XYZ tristimulus values for the corresponding RGB values of the iPhone display were measured. At this time, we conducted measurements in a lighting booth that the brightness of the light source was adjusted in four steps. A total of 26 types of illuminance or chromaticity were measured under different light sources.



- Measurements in the dark and under26 light sources of lighting booth

Results & Discussion:

< Reliability of skin information evaluated through skin spectrum matching >

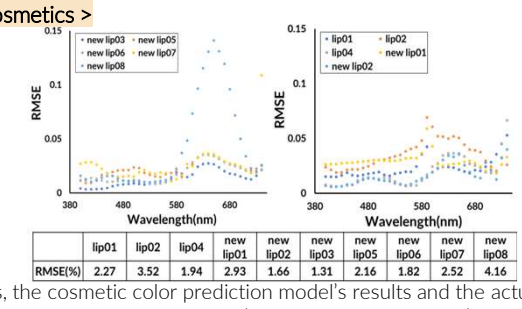


For cheeks and forearms, excluding the lips, the p-value is less than 0.05 and the correlation coefficient (r) is greater than 0.7, so it can be concluded that $f_{Melanin}$ and MI are proportional.

Also, it can be seen that the higher the $f_{Hemoglobin}$ obtained through skin spectrum matching, the higher the EI. (p-value < 0.05, and correlation coefficient (r) > 0.7)

Therefore, skin information evaluated through skin spectrum matching is reliable.

< Accuracy of the cosmetic color spectrum prediction model of the skin using the optical properties of cosmetics >



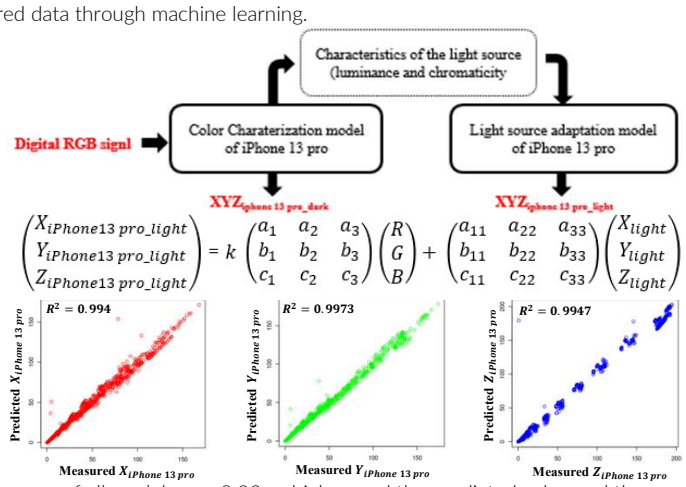
	lip01	lip02	lip04	new lip01	new lip02	new lip03	new lip05	new lip06	new lip07	new lip08
RMSE(%)	2.27	3.52	1.94	2.93	1.66	1.31	2.16	1.82	2.52	4.16

For ten lipsticks, the cosmetic color prediction model's results and the actual cosmetic color applied to skin were compared using RMSE (Root Mean Square Error) for the entire spectrum.

The largest error is less than 0.045 (less than 4.5%), so the cosmetic color spectrum prediction model is considered to be accurate.

< Machine learning algorithms for color matching model >

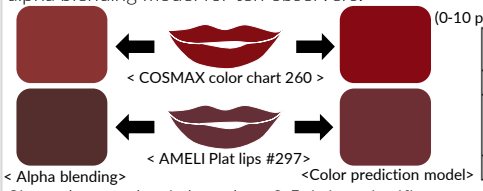
For high accuracy and reproducibility in mobile makeup simulation, we propose an algorithm that can predict the display color of the iPhone 13 Pro under a light source according to the input RGB value. All models were derived by performing multiple regression analysis on measured data through machine learning.



The accuracy of all models was 0.99 or higher, and the predicted value and the measured value were almost identical to each other. Through the proposed process, it was possible to obtain the input RGB value for which the target color(XYZ value) is displayed.

< Total Result of Non-face-to-face color prediction model >

A comparing survey was conducted on the non-face-to-face color prediction model with the alpha blending model for ten observers.



(0-10 point : The more similar the colors, the higher the score)

Lip stick	COSMAX color Chart 260	AMELI Plat lips #927
Alpha blending	6.33	4.00
Non-face-to-face color prediction model	7.67	8.00
p-value	0.05	0.00029

Since the p-value is less than 0.5, it is a significant result, so it is considered that the result through our research model is more similar to lip color than Alpha blending.

Conclusions:

From this research, we can offer a system to virtually represent individual skin conditions and the color of natural human skin covered with cosmetics. Our study identified four things.

Firstly, It was confirmed that the skin information evaluation method using the skin spectrum is reliable by comparing it with the skin information evaluated through the Mexameter.

Secondly, because the error between the predicted and actual spectra was small, it was confirmed that the cosmetic color spectrum prediction was accurate.

Thirdly, by applying a color matching model according to the display and light source, colors similar to reality can be implemented on the display.

Finally, consumers can check the color of skin covered with cosmetics by smartphone to help them purchase cosmetics.

Acknowledgements:

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