Poster: Wearable Sensing for Measuring Skin-Tone, Melanin, and Erythema

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***Abstract*—Accurate, continuous monitoring of skin characteristics like melanin, erythema, and skin tone is critical for both dermatological and cosmetic applications. Traditional methods, such as colorimeters and spot measurements, provide accurate but limited data and often fail to represent diverse skin tones effectively. Additionally, wearable health devices, such as pulse oximeters, often show inaccuracies in individuals with darker skin, exacerbating health disparities. There is a growing need for a cost-effective, non-invasive solution that can provide real-time, continuous skin measurements across various skin types. Our prototype system aims to address these gaps and has shown promising preliminary results in early testing.**

I. Introduction

Melanin, erythema, and skin-tone are important indicators of cosmetic and medical conditions, influencing skin appearance and health. While devices like colorimeters traditionally used in these settings provide accurate measurements of the skin, they are expensive and limited to spot checks, making them less practical for continuous monitoring [1]. Additionally, wearable devices like pulse oximeters often produce inaccurate readings in individuals with darker skin tones, exacerbating health disparities [2]. To address these issues, we developed a prototype system for continuous, non-invasive monitoring of skin properties.

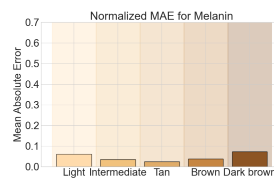
II. Methodology

We used the Cortex DSM-IV [3] colorimeter as a reference measurement, a device commonly used in cosmetic contexts and is known for its precise reporting of melanin, erythema, and skin tone across the visible spectrum. Our prototype employs an off-the-shelf wearable device [4], able to be fit in various form-factors, with LEDs and photodiodes (400-1000nm) to capture reflectance data from the skin. In an IRB-approved pilot study with nine participants of diverse skin tones, we collected measurements from multiple body sites, including the wrists, fingers, shoulder, and forehead, using both the prototype and the DSM-IV.

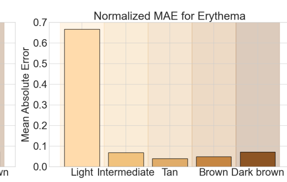
We developed a 5-fold cross-validated machine learning algorithm that utilizes the direct current (DC) frequency content of the resulting LED-PD measurements across the visible spectrum, combined with other features such as volume under the curve (VUC), to accurately quantify melanin, erythema, and skin-tone. Furthermore, we developed a model trained on PhysioNet data utilizing blood oxygen and corresponding spectrophotometer measurements to analyze the effect of incorporating skin properties into blood oxygen measurements. This model normalizes the predicted blood oxygen measurement from the pulse oximeter with skin-tone information, correcting for inaccuracies by up to 50% in both normal and hypoxic conditions across skin-tones.

III. Results and Conclusions

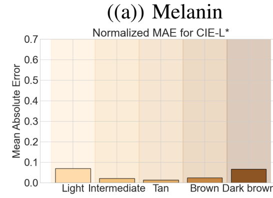
The results below demonstrate the performance of our model's predictions using normalized MAE. Our model excels at measuring melanin (a) and skin undertones (c, e), but struggles with erythema (b) and redness (d) in lighter skin tones. We anticipate improved performance with a larger sample size.



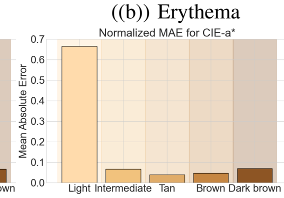
((a)) Melanin



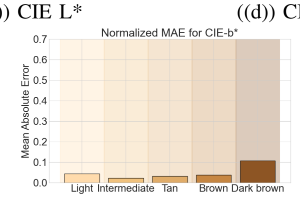
((b)) Erythema



((c)) CIE L*



((d)) CIE A*



((e)) CIE B*

Fig. 1: Normalized MAE across targets, grouped by skin-tone

References

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[2] A. F. et al, "Racial and ethnic discrepancy in pulse oximetry and delayed identification of treatment eligibility among patients with covid-19," *JAMA*, vol. 182, no. 7, pp. 730–738, 2022.

[3] Cortex, "Dsm 4," Digital spectrophotometer for dermatological assessments, 2024.

[4] A. W. et al, "Lumos: An open-source device for wearable spectroscopy research," *IMWUT*, vol. 6, no. 4, jan 2023.