An Anthropological Basis for Skin Rendering

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ABSTRACT

Skin rendering algorithms in graphics have historically drawn from the medical literature, and thus inherited historical biases that are becoming more widely recognized. We advocate for a shift towards the *anthropological* literature, which offers not only a more holistic view of human variation, but a wealth of measurement data that can be leveraged in graphics research.

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1 INTRODUCTION

Current understandings of skin color variation in computer graphics are informed by the medical literature. For example, the commonly used dipole approximation for skin [Jensen et al. 2001] originated in this literature [Eason et al. 1978; Farrell et al. 1992], and the most commonly used classification scheme for skin color is the Fitzpatrick scale from dermatology [Weyrich et al. 2006]. Computer graphics researchers turned to this corpus because it is concerned with the biology of skin. However, medicine broadly lacks an adequate framework for understanding normal, non-pathological variation across populations. Instead, characterizing the wide range of "healthy" variation is secondary to understanding pathology (disease) relative to a universal, default state.

Dermatology, in particular, has historically centered light (European) skin, as this branch of medicine has been viewed as a luxury and focused on developing treatments for privileged demographic groups. Recent initiatives have sought to broaden this focus, including the *Skin of Color Society* which draws attention to conditions afflicting darker-skinned individuals. Due to this historical (and present) neglect of the full range of human variation, the dermatological literature is not a reliable source for information on skin color variation. Computer graphics models based on this literature will have similarly narrow understandings of skin pigmentation.

As an alternative, we propose the computer graphics community turn its attention towards *anthropology*, where one of the central goals is to understand human biological variation. In particular, skin color variation has been of recent interest in the anthropological genetic literature. Over the last five years, there has been a surge in genetic studies of quantitative skin pigmentation across populations in Africa and the Americas [Adhikari et al. 2019; Martin et al. 2017], in addition to decades of existing data collected by anthropologists [Jablonski and Chaplin 2000; Relethford 2000]. This vast collection, *which includes reflectance data*, is an untapped resource for rendering the full range of human skin color variation.

2 ANCESTRY VS. SKIN COLOR

A better understanding of the nature and distribution of human biological variation would help inform graphics work on skin. Currently, terms such as *skin type* and *ethnicity* are used to describe various dimensions of human diversity, and often presented as intrinsically related. However, this conflates two very distinct biological concepts. *Skin type* is mainly used to describe pigmentation, which is not a categorical (discrete) trait, but a continuously varying one. *Ethnicity* is used to categorize people into populations that are presumed to be more closely related to each other and similar in appearance. The closest biological concept to this is *ancestry*.

Skin pigmentation cannot be used as a proxy for ancestry, nor can ancestry index skin pigmentation [Mathieson and Scally 2020]. Human biological variation is shaped by (genetic) relatedness (i.e., ancestry) and selective pressures. Skin color is strongly shaped by how natural selection has affected populations inhabiting regions with different amounts of ultraviolet radiation [Jablonski and Chaplin 2000]. As such, there are individuals who might be grouped by broad geographical ancestry, but have more dissimilar skin colors than two people with more divergent ancestries. For example, Southeast Asians and Northeast Asians might be broadly grouped as East Asians, but their skin tones may differ more than, Northeast Asians and Northern Europeans (top plots, Fig. 1).

This distinction between skin pigmentation (or any other trait) and ancestry is even more important when considering individuals with *admixed* ancestry (i.e., ancestry from multiple distantly related groups). Often the terms "African American" and "African" are used interchangeably, but African Americans are a population with both European and (West) African ancestry [Parra et al. 1998]. This distinction is important because there is considerable overlap in skin color between Europeans and European-African admixed populations like African Americans. Moreover, by relying on African Americans as proxies for Africans, we are neglecting the full range of variation found across the African continent [Martin et al. 2017; Parra et al. 1998] (bottom plots, Fig. 1).

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Attempting to produce a single template for skin rendering for each "ethnicity" inevitably necessitates a certain level of homogenization. This is especially problematic in admixed populations as they have a wider range of skin color variation than each of their ancestral populations (see Fig. 1).

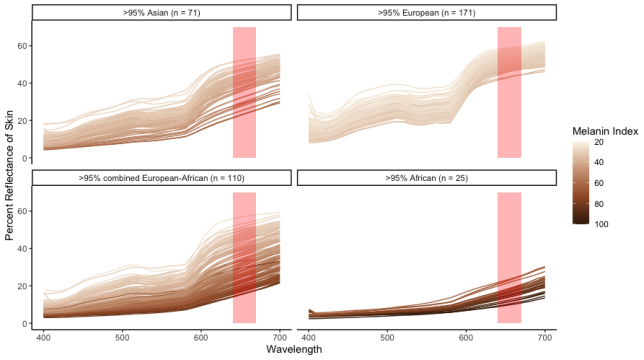

Figure 1: Forehead reflectance spectra across genetic ancestries (n=377). Each line is a shade of brown representing an individual's M-Index. Red strips are wavelengths used for M-Index. Data was collected under PSU IRB #44929 and #45727.

3 FUTURE RESEARCH

We suggest that future skin rendering research work to detangle ancestry from skin pigmentation by adopting more accurate approaches to conceptualizing and describing both these phenomena.

In addition to ensuring datasets represent a wide range of self-reported ethnicities and ancestries, researchers should attempt to collect data from a wide range of skin pigmentation within and across those groups. For this purpose, we recommend using the Melanin Index (M-Index) as a standardized measure to communicate skin pigmentation [Fullerton et al. 1996]. This measure can be collected with skin-specific portable reflectance spectrophotometers [Piérard 1998] with the option of collecting broad or narrow band visible light spectra. Skin-specific spectrophotometers provide M-index directly, but it can be calculated from any reflectance measurements that includes data between ~625 and ~685 nm according to: M-index = $100 \log \frac{1}{I_{red}}$, where I_{red} is the percentage reflectance over that range [Fullerton et al. 1996].

We compare M-index (calculated from broad-spectrum reflectance) with Fitzpatrick skin types for a large sample (n=377) of individuals with a wide range of genetic ancestries to demonstrate how the Fitzpatrick scale collapses the large range of variation in M-index found outside of European populations (see Fig. 2).

M-index is considered a better approximation of pigmentation biology because it more closely reflects the genetic architecture of pigmentation around the world [Martin et al. 2017]. Thus, it does not appear to be arbitrarily trading compression in one region of variation in favor of another. On the contrary, when comparing various skin color measures to CIELAB values, M-index produces a nearly linear perceptual response, whereas Fitzpatrick distorts the range of variation by compressing the darker end of the skin color spectrum [Shriver and Parra 2000].

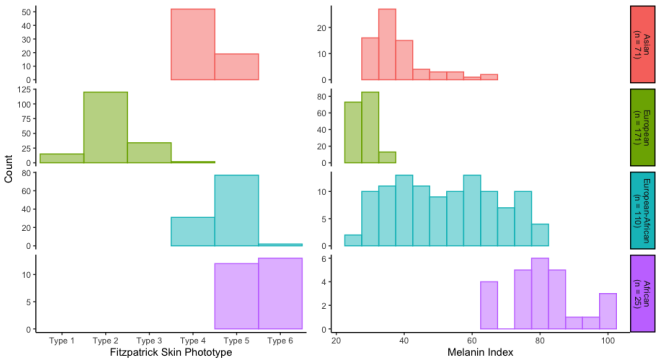

Figure 2: Fitzpatrick (left) vs. Melanin Index (right) across continental groupings. Fitzpatrick compresses the ranges with most variation into Types V and VI. In particular, European-African (third row) expands into 3/4 of the entire M-index range. Data is the same as Fig.1.

Certainly, M-index is not a comprehensive metric. As we show in Figure 1, M-index approximates the proportion of light reflected in the red part of the spectrum, but it does not explain some of the interesting variation we observe in the shape of the spectral traces across these broad population groupings. However, with the proposed framework for conceptualizing human biological variation, future research can explore the space of appearances that is not captured by M-index. This research has the potential to contribute to multiple disciplines, as it could help close the gap between our understanding of (color) perception and objective biological processes underlying skin color.

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