Countering Racial Bias in Computer Graphics Research (Supplement)

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1 SKIN PAPERS

1.1 White Skin Papers

Many of the works on subsurface scattering focus on fair, white skin, but refer to it solely as "skin" [22, 39, 52, 68], "human skin" [20, 38, 61, 62], or a "human face" [16, 37]. The final showcase renderings solely feature images of white skin. In those works, it is unclear if the same algorithms are applicable to all types of skin, or whether the phenomena being captured by the algorithms are equally relevant to other skin types. While some papers also feature images of East Asians, the skin tones involved can be the fairest of all the examples [17], so the question of generality remains.

Other papers do attempt to build more complete models of human skin, incorporate different Fitzpatrick types into their studies, and render skin patches in a wide range of shades, but again the final showcase images are solely of white skin [23]. Others have a narrow range of test subjects, e.g. Jimenez et al. [41] reports collecting data from "one Caucasian female, 33 years old; three Caucasian males, 26, 33, and 35 years old", or see Figures 1 and 19 in Beeler et al. [2]. In other works [24], skin variations are presented, but only deal with sweat, oil, ink, blood, and dirt. Both the final renderings and reference images are all of white skin.

The scan of Lee Perry-Smith's head is often used as the sole skin benchmark in papers [26, 29, 46, 63], which suggests that the development of other benchmarks would help diversify research practices. Other works include more than one head example, e.g. [42] appears to contain four, but they are all of white humans.

In all, we found 19 rendering papers that solely featured white skin. We also found 4 instances where this bias is inherited by commercial software [55, 58–60], where their demos and documentation feature solely renderings of white humans. These lists are almost certainly incomplete.

1.2 Skin Papers with More Diversity

Some skin papers explore the appearance space more broadly. For example, both Hanrahan and Krueger [32] and Krishnaswamy and Baranoski [48] modulate the level of melanin, and Marschner et al. [50] captures data from "a 43-year-old Caucasian male and a 23-year-old male from India." Donner and Jensen [21] present a spectral model for skin that also attempts to capture "Asian" and "African" skin, though the final showcase renders are again only of white skin. In one of the largest-scale studies to date, over 100 subjects of various skin phototypes, as classified by Fitzpatrick scale, were recruited for Weyrich et al. [67], and ten different skin shades appear in the illustrations for that paper. Finally, three subjects of Mediterranean, South and East Asian descent were recently used to illustrate the method in Gitlina et al. [27].

Some works are notable in the striking diversity of their generated avatars [34, 70]. A recent facial capture paper includes a variety of subjects [28], but notably does not attempt to capture subsurface scattering parameters. Instead, it sets them uniformly across all subjects, with the subsurface scattering color varying according to the subject's surface albedo. (Note that "albedo" is Latin for "whiteness".) The relative importance of the phenomenon in darker skin is still unclear.

2 HAIR PAPERS

2.1 Hair Simulations

Some of the earliest work in hair simulation deals exclusively with straight hair [1, 12]. This straightness assumption then leads to approximations using sheets [47], extruded sheets [69, 73], or clusters [8] instead of individual strands. Subsequently, simulations of straight or wavy hair are usually referred to simply as "hair" or "human hair" [3, 4, 6, 7, 9, 11, 13, 14, 19, 25, 30, 31, 33, 40, 44, 64–66].

In at least one instance [51], the fact that the algorithm excels explicitly at *straight* hair is mentioned in the title. In another [35], the shortcomings of existing straight-hair models are foregrounded by the need to develop a *curly* hair model. The definition of *curly* remains ambiguous, as other works [74] contain much straighter hair that is still characterized as "curly".

In all, we found 27 papers dealing with the simulation of straight-to-curly hair. In contrast, we only found one paper that deals with simulating kinky, $(0 + 1i)$ hair. A Cosserat model is used to model a variety of hair styles [5], including kinky, high-curvature strands. Patrick et al. [57] also modeled long, braided $(0 + 1i)$ hair, as well as short $(0 + 1i)$ hair, but did not attempt any simulations. Bertails et al. [4] mentions the non-zero natural twist in "African" hair, but does not attempt to simulate it.

2.2 Hair Rendering

Hair rendering algorithms focus exclusively on straight-to-curly hair. Kajiya and Kay [43] formulated a hair rendering model specifically for fur, and approximated the fibers as straight cylinders. The model of Marschner et al. [49] modified this cylinder to include cuticle scales, and subsequently demonstrated the secondary highlights that appear. Extremely straight $(1 + 0i)$ hair is used to showcase this feature (see its Figs. 12-15). It remains unclear how prominent this feature is in $(0 + 1i)$ hair. Other works test their algorithms on straight ponytails [36, 53], a single curly lock [18], or head models covered in straight or wavy hair [15, 56]. The model of Khungurn and Marschner [45] incorporates the measured elliptical cross-sections of several different types of hair, but the final renders are all of straight or curly blonde hairs (see its Fig. 21).

Several works specifically focus on the subsurface scattering phenomena characteristic of light, blonde hair. The model of Moon et al. [54] deals with "multiply scattered light [that] predominates in blond and other light colored hair", and Zinke et al. [75] first observe that "particularly in dense, light-colored hair, multiple scattering provides a critical component of the hair color," before proceeding to develop a model for that case.

Recent work has revisited the problem of animal fur [10], and in particular modified the model of Marschner et al. [49] to include the medulla characteristic of animal fur [72]. The fur models have then been unified with "human hair" [71] (see its Fig. 18), and the "human hair" presented is consistently straight.

In all, we found 14 hair rendering papers featuring straight-to-curly hair. This list is almost certainly incomplete. The only paper we found for rendering $(0 + 1i)$ hair was the previously mentioned Patrick et al. [57], which proposes a modified Kajiya-Kay model for dense, braided, and short, unbraided $(0 + 1i)$ hair.

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