Measurement and Modeling of Microfacet Distributions under Deformation

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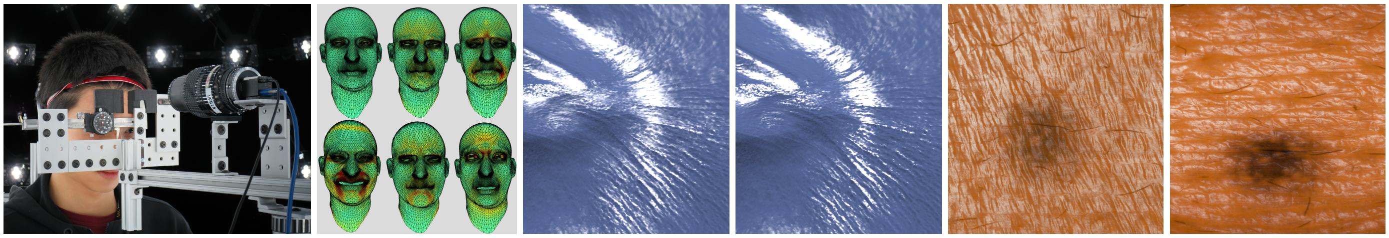

(a) (b) (c) (d) (e) (f)

Figure 1: *(a) Stretching skin measurement setup. (b) Ratio of anisotropic surface strain computed on a captured geometry sequence. Rendered surface reflectance of the crow's feet on a smile expression with dynamic (c) and static (d) microfacet distributions. Dynamic microgeometry rendering of a forehead skin patch under a point light under stretch (e) and compressions (f).*

Abstract We endeavor to model dynamic microfacet distributions of rough surfaces such as skin to simulate the changes in surface BRDF under stretching and compression. We begin by measuring microfacet distributions at 5-micron scale of several surface patches under controlled deformation. Generally speaking, rough surfaces become flatter and thus shinier as they are pulled tighter, and become rougher under compression. From this data, we build a model of how surface reflectance changes as the material deforms. We then simulate dynamic surface reflectance by modifying the anisotropic roughness parameters of a microfacet distribution model in accordance with animated surface deformations. Furthermore, we directly render such dynamic appearance by driving dynamic micro geometries to demonstrate how they influence the meso-scale surface reflectance.

Introduction Surface roughness of an object is an important feature to model as it determines the impression of the surface appearance. When an object undergoes stretch and compression, the deformation changes surface reflectance as can be seen in a deflated balloon that exhibits dull specular highlights whereas the highlights appear sharper when inflated. This characteristic also applies to human skin. A great deal of work has been done in simulating subsurface reflectance of human skin including dynamic effects. However less attention has been given to dynamic surface reflectance.

Measurement We record the microstructures of patch exemplers including human skin with similar set up with [Graham et al. 2013] using polarized gradient illumination (Fig. 1(a)). The sample patches are scanned in different deformed states in a LED lighting dome with a custom stretching measuring device consisting of a caliper and a stretching aperture. The aperture of the patch holder is set 8 mm for the neutral deformation state and is set 30 cm away from a Ximea camera which records monochrome 2048 by 2048 pixel resolution image with Nikon 105 mm macro lens stopped down to f/16. We used 16 different lighting conditions on a hemisphere similar to [Graham et al. 2013] including polarized and unpolarized lighting, and computed a per-pixel surface normal map as well as specular and subsurface albedo maps from the polarized gradients.

Roughness Model [Ferguson and Barbenel 1981] noted an inverse relation between surface roughness of human skin and the amount of stretch. They also showed that surface roughness exists as a reserve of tissue, allowing the skin to stretch up to a certain point. Our roughness model is based on this relationship, where the surface stress alters the surface roughness, and thereby changing the surface appearance. It starts with computing 2D anisotropic surface stress given a sequence of dynamic geometry (Fig. 1(b)). By investigating the variance of micro-scale surface orientations from the captured data, we determine surface microfacet distributions along with the known amount of stress. Once this relation is established, we look up the corresponding variance value for each stress axis to determine the roughness parameter. We compute the 2D surface stress on each triangle frame of a mesh, and interpolated per pixel stress for look up. More details are provided in the supplemental material.

Results of BRDF Model Fig. 1 (c) and (d) show surface reflection rendering of crow's feet on a smile expression rendered by the dynamic and static microfacet models, respectively. As the skin surface is crinkled, it exhibits more variation of surface orientations in a preferred direction, making the surface rougher in a certain manner. The dynamic model produces believable rougher specular highlights over the wrinkles.

Rendering Dynamic Microgeometry At the scale of our measurement, where much of the geometric variation is evident, we can directly render dynamic surface reflectance by driving surface geometry. For rendering, we corresponded captured surface normal maps as well as specular and diffuse albedo maps per pixel using the Vuvuzela correspondence tool. Under stretching (Fig. 1(e)) and compressions (Fig. 1(f)), the patch forms micro scale surface grooves and ridges in a different manner, and therefore results in different surface reflectance at the meso scale as can be observed in the real life.

References

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