SVBRDF estimation using a normal sorting technique

Snehal Padhye, David Messinger, James Ferwerda
Rochester Institute of Technology

RIT College of Science, Chester F. Carlson Center for Imaging Science

SIGGRAPH 2022 VANCOUVER+ 8-11 AUG

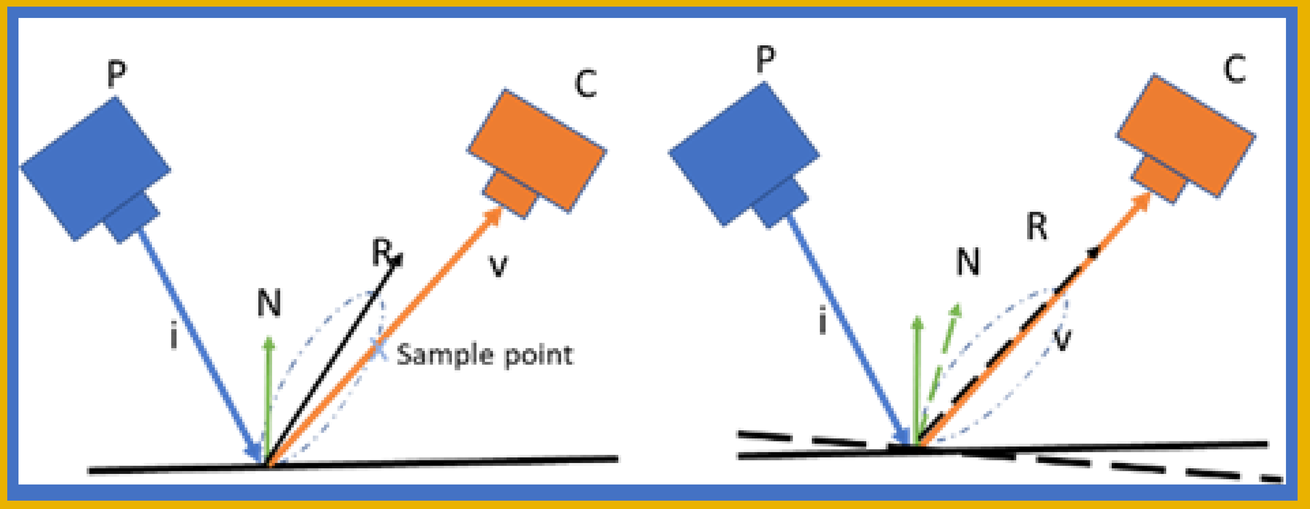
PROBLEM

- Spatially varying bidirectional reflectance distribution functions (SVBRDFs) play an important role in appearance modeling of real-world surfaces.
- Automatic capture of these surface properties is highly desirable.
- We propose a novel approach towards estimating the complete SVBRDFs of surfaces using a portable projector-camera system made of standard consumer-grade components.
- Our technique should be of great value to practitioners seeking to model and render the geometric and reflectance properties of complex real-world surface.

RELATED WORK

Structured light techniques have been widely used for 3D modeling of objects [1]. But capturing SVBRDFs using structured light is challenging, which is often the main limitation in using it for modeling the complete appearance of objects. Baek et al. [2] used polarimetric images with the structured light setup to measure surface roughness and Rushmeier et al. [3] used multiple pairs of cameras and projectors with high spatial frequency patterns to estimate SVBRDFs. We describe a generic and simple approach to estimate both the topography and SVBRDFs of complex surfaces within the structured light setup.

APPROACH

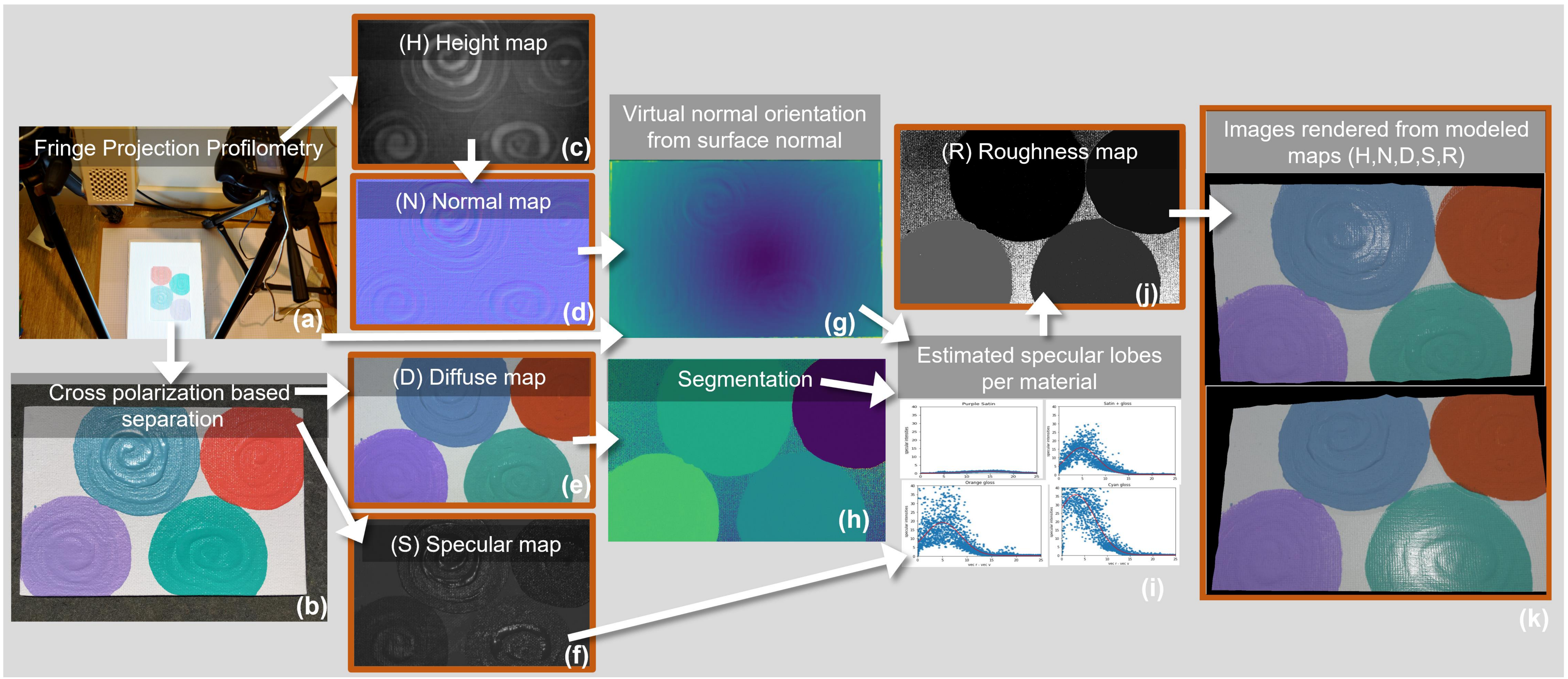


- We use well-established techniques to estimate diffuse, specular and normal component of the SVBRDF.
- To estimate the roughness component of the SVBRDF, we observe that:
  - For a smooth, homogenous surface, the magnitude and rate of change of specular intensity vary with surface roughness and illumination/view angles.
  - A pro-cam system illuminates and views a surface from a regular family of illumination and view angles.
  - The projective geometry of our pro-cam system can be used along with the normal maps estimated by the system to "unscramble" the specular maps associated with different materials and thereby estimate the roughness components of their SVBRDFs.

REFERENCES

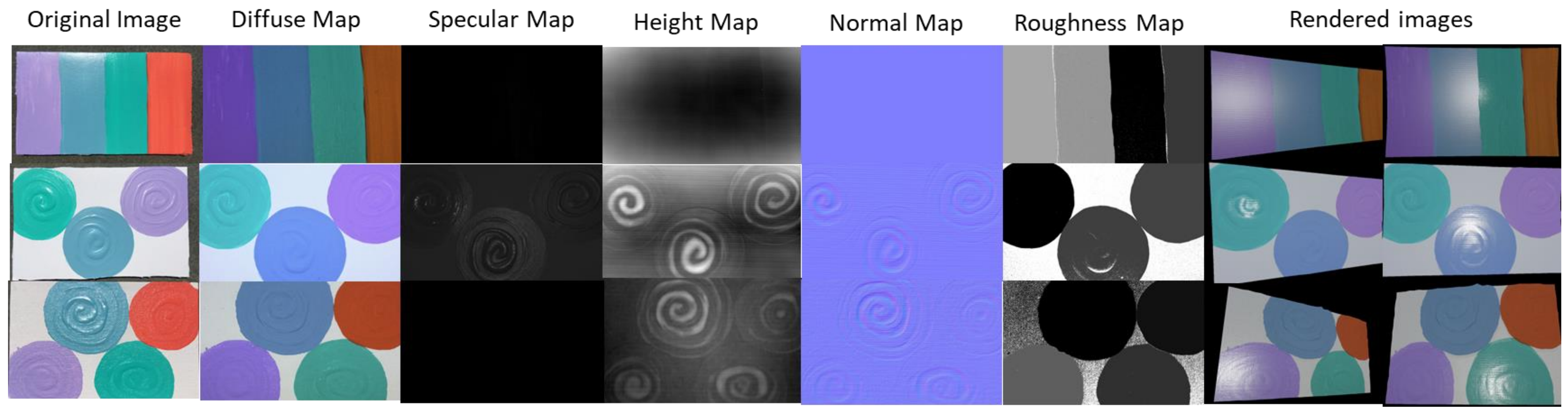
1. Jason Geng. 2011. Structured-light 3D surface imaging: a tutorial. Adv. Opt.Photon. 3, 2 (Jun 2011), 128–160.
2. Seung-Hwan Baek, Daniel S. Jeon, Xin Tong, and Min H. Kim. 2018. Simultaneous acquisition of polarimetric SVBRDF and normals. ACM Transactions on Graphics (TOG) 37 (2018), 1 – 15.
3. Holly Rushmeier, Yitzhak Lockerman, Luke Cartwright, and David Pitera.2015. Experiments with a low-cost system for computer graphics material model acquisition, Vol. 9398. International Society for Optics and Photonics, SPIE, 35 – 43.
4. Peisen S. Huang, Qingying J. Hu, and Fu-Pen Chiang. 2002. Double three-step phase-shifting algorithm. Appl. Opt. 41, 22 (Aug 2002), 4503–4509.
5. NCS. 2022. NCS Gloss Scale. https://ncscolour.com/product/ncs-glossscale/

METHOD



- Structured light setup, equipped with polarizers, used to estimate the specular and diffuse reflectance components of the SVBRDF.
- Fringe projection profilometry (FPP) [4] used to derive height and normal maps.
- Pro-cam setup is calibrated to get the positions and orientations of imaging plane, camera center and projector center in world coordinates.
- *Virtual normals* are calculated for each pixel using the pro-cam geometry.
- Next, the diffuse map is used to segment the surface into different materials.
- Specular intensities in the different segments are sorted with respect to the virtual normal.
- The sorted specular intensities are plotted, and Gaussian curves are fitted to the resulting distributions.
- The standard deviations (SDs) of these distributions are proportional to the micro-scale roughnesses of the different materials.
- Technique is applied to the NCS gloss standards [5] to scale the measured SDs to surface roughness values.
- Estimated values are propagated to each pixel to generate roughness, height, normal, diffuse and specular maps of the surface.

RESULTS



LIMITATIONS AND FUTURE WORK

While we believe this work represents a significant advance in image-based methods for surface appearance capture, there is still much work to be done.

- First, at this time we can only estimate the SVBRDFs of isotropic materials and adapting the method for anisotropic materials would be valuable.
- Second, the FPP method is fast, and can measure small surface variations, but models sometime have high spatial frequency artifacts which may cause errors in normal estimation for surfaces with very small variations.
- Third, for near-planar surfaces made of many different materials we will likely need to capture multiple images of the surface at different positions across the system's field of view.
- Fourth, the accuracy of our approach is sensitive to the segmentation algorithm and exploring the accuracy of different segmentation algorithms under different conditions would be a useful exercise.
- Finally, future work also involve extending and validating the method for a wider range of surfaces and materials and extending the method to handle translucent materials.