Linearly Transformed Spherical Harmonics (LTSH)

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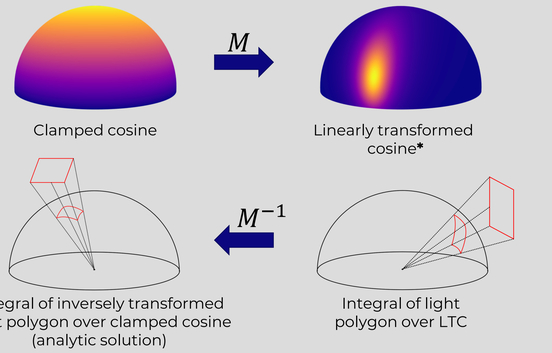
Problem

- Direct illumination for Lambertian polygonal area lights
- No analytic solution for integral of BRDF over polygonal domains
- Numerical solution too expensive for real-time applications

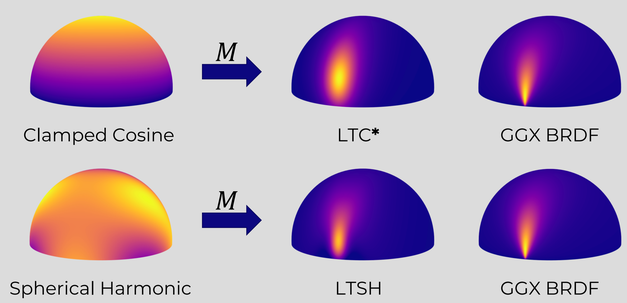
Recap of LTCs[1]

- Approximate BRDF with linearly transformed cosine (LTC)
- Inversely transform light polygon
- Calculate integral of spherical function
- Create look-up-table of transformations $\boldsymbol{M}$ for different roughness values and incident directions for use in shading

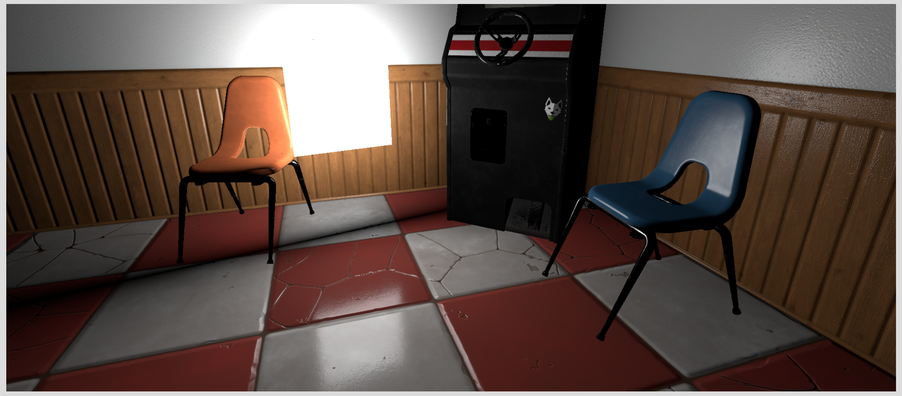


Our Approach

- Use spherical harmonic expansions as spherical functions
- Increases degrees of freedom to find BRDF approximations
- Linear least squares finds optimal SH expansion for any transform $\boldsymbol{M}$
- Non-linear least squares optimizes $\boldsymbol{M}$ using the linear optimization inside
- Closed-form integral of SH over polygonal domains is available[2,3]
- For integration we use an existing implementation[2]

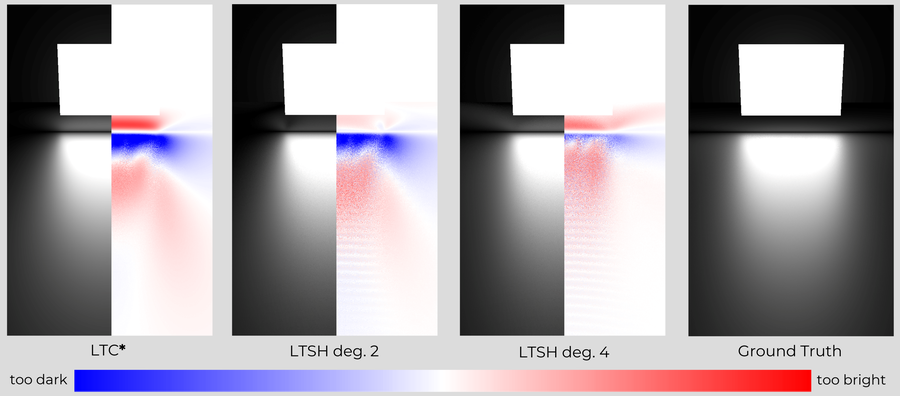


Results



Arcade scene rendered with LTSH deg. 4

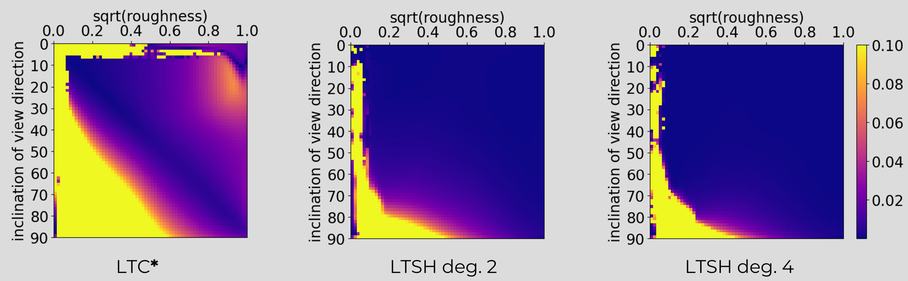
Ground Truth Comparison



Area light over a flat plane rendered with different specular shading techniques

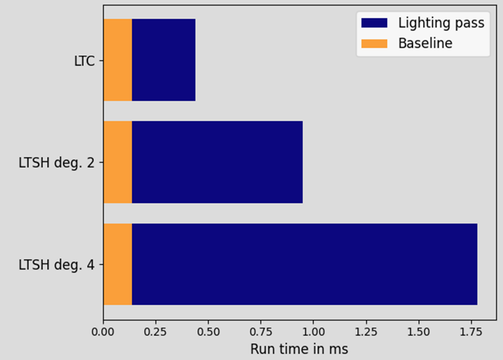
Error Comparison

Mean squared error over hemisphere for the whole 64x64 look-up-table, capped to 0.1



Run Times

Rendered with an RTX 2070 Super at 1920x1017 pixels



Baseline (no shading): 0.14ms, LTC: 0.44ms, LTSH 2: 0.95ms, LTSH 4: 1.78ms

Comparison to LTC*

+ Quality improvement
+ Adaptive through degree of SH expansion
+ In theory never worse than LTC because LTC ∈ LTSH of deg. ≥ 1

- Significantly slower
- No textured lights
- No linear interpolation between fits

* We fitted our parameters with a naïve proof of concept implementation that might be worse than actual LTC[1].

Future Work

- Refine fitting process
- SH integration code[2] is optimized for SH of degree 8, speedup of shading possible by optimizing for degree in use
- May generalize to linear and disc lights

References

1: Eric Heitz, Jonathan Dupuy, Stephen Hill, and David Neubelt. Real-time polygonal-light shading with linearly transformed cosines. ACM Trans. Graph., 35(4):41:1–41:8, 2016. ISSN 0730-0301. URL: http://doi.acm.org/10.1145/2897824.2925895.
2: Jingwen Wang and Ravi Ramamoorthi. Analytic spherical harmonic coefficients for polygonal area lights. ACM Trans. Graph., 37(4), 2018. ISSN 0730-0301. URL: https://doi.org/10.1145/3197517.3201291.
3: Laurent Belcour, Guofu Xie, Christophe Hery, Mark Meyer,Wojciech Jarosz, and Derek Nowrouzezahrai. Integrating clipped spherical harmonics expansions. ACM Trans. Graph., 37(2), 2018. ISSN 0730-0301. URL: https://doi.org/10.1145/3015459.