

Eigentransport for Efficient and Accurate All-Frequency Relighting

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Motivation

- SH and Haar are the bases most used for static PRT applications
- If we treat diffuse PRT as a data compression problem, we can get better reconstruction with less coefficients
- Assumptions
 1. Static scenes with diffuse surfaces
 2. Distant environmental lighting

Previous Work

- Seminal works by Kautz et al. and Sloan et al. started SH trend for PRT
 - Gautron et al. manipulate this basis to yield Hemispherical Harmonics
- Ng et al. [03,04] use Haar wavelets for “all frequency” effects
 - Ma et al. use a spherical Haar basis
- Sloan et al. perform CPCA over SH for compression of large datasets
- Directional bases have also been used by Lehtinen and Kautz
- Kristensen et al. perform PCA over distributed point sources for indirect reconstruction

Main Idea

- Current bases are scene agnostic
 - By tailoring the basis to the scene data we can obtain lower reconstruction error with fewer coefficients than with current SH or Haar
- Treat the sampled cosine-weighted visibility function at a vertex as a vector in a high-dimensional space
- Perform PCA over all vertices of the scene
- This will yield an orthonormal basis (eigentransport) for representing the data

Orthonormal Basis

- The *eigentransport* basis is simply the eigenvectors of the PCA decomposition
- An orthonormal basis will allow us to reconstruct the double product integral of lighting with cosine-weighted visibility using a dot product of their projection vectors

$$\begin{aligned} B(\bar{x}) &\approx \frac{\rho}{\pi} \int_{\Omega_{\mathbf{n}\bar{x}}} \left(L_{env}^c \cdot \mathcal{B} + \tilde{T} \right) \left(T_{\bar{x}}^c \cdot \mathcal{B} + \tilde{T} \right) d\omega \\ &\approx \frac{\rho}{\pi} \int_{\Omega_{\mathbf{n}\bar{x}}} \left(L_{env}^{c'} \cdot \mathcal{B} \right) \left(T_{\bar{x}}^{c'} \cdot \mathcal{B} \right) d\omega \\ &= \frac{\rho}{\pi} \left(L_{env}^{c'} \cdot T_{\bar{x}}^{c'} \right) \int_{\Omega_{\mathbf{n}\bar{x}}} (\mathcal{B} \cdot \mathcal{B}) d\omega \\ &= \frac{4\rho}{s} \left(L_{env}^{c'} \cdot T_{\bar{x}}^{c'} \right) \end{aligned}$$

Pipeline Differences

- Eigentransport can easily be integrated into current art pipelines

Precomputation

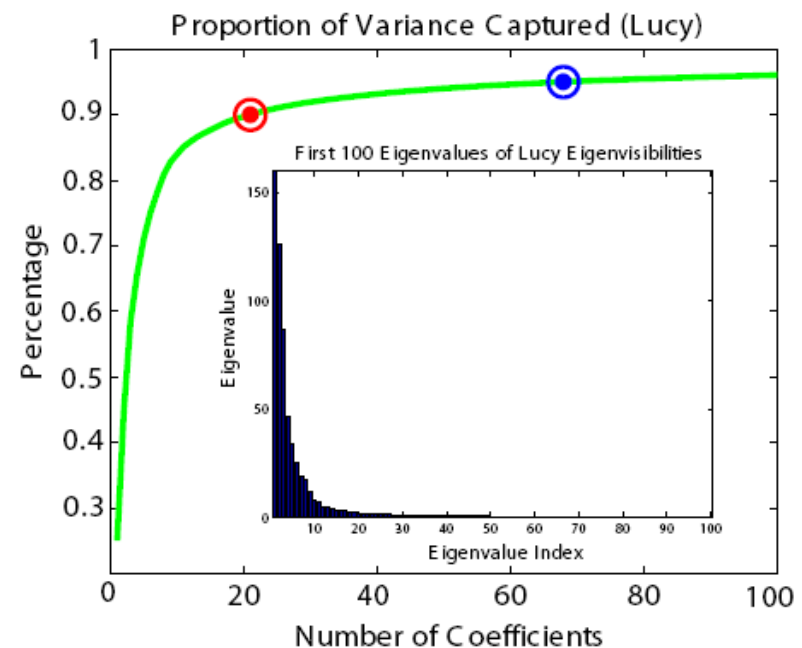
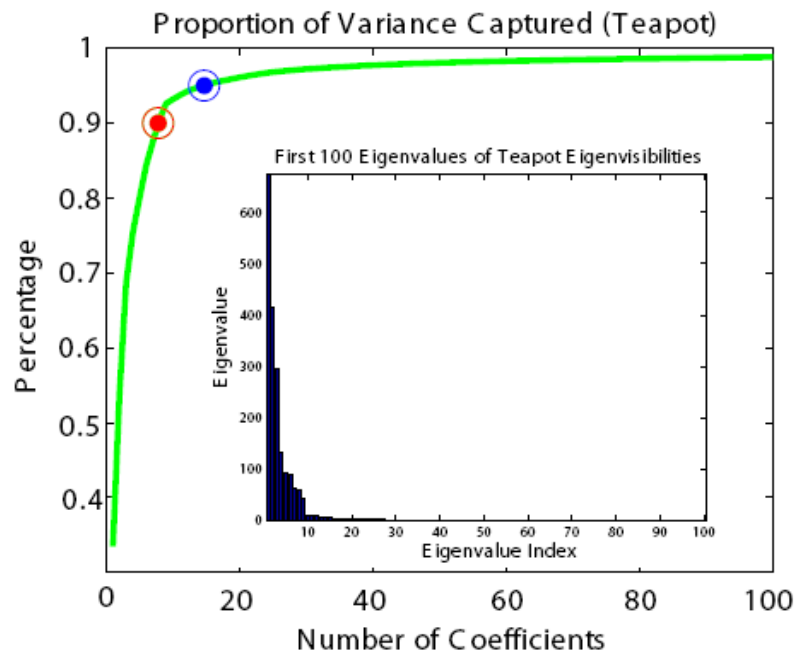
- Same as current PRT, except perform PCA to project into eigenbasis
 - Store size n coefficient vector at each vertex
 - Store the first n PCA basis vectors for dynamic lighting

Runtime

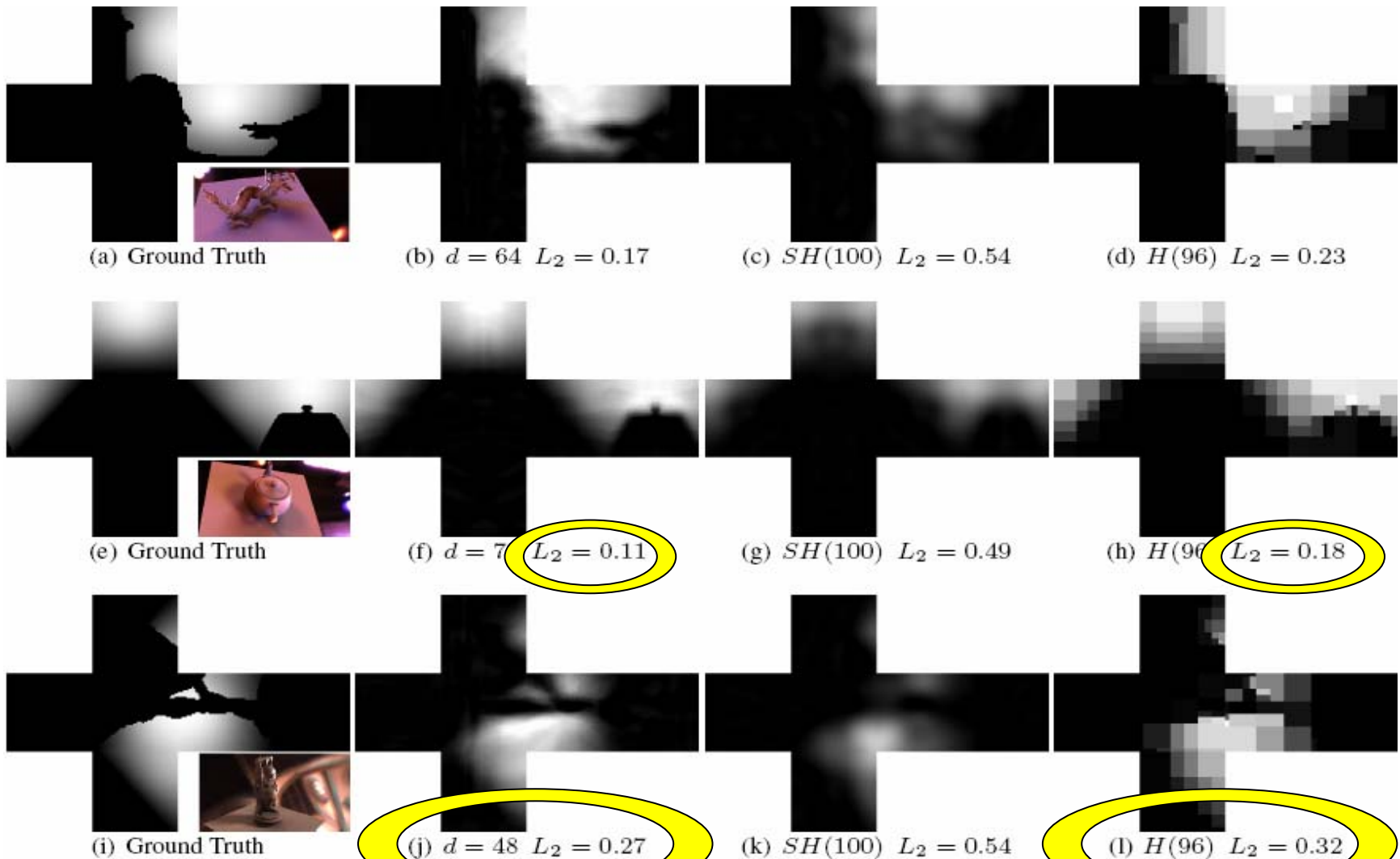
- Project lighting into eigentransport basis
- Dot lighting coefficients with per-vertex projection coefficients (details in the paper)

How do we pick n ?

- Unlike Wavelet PRT, linear approximation is used
 - We pick n in order to capture a certain percentage of the variance of the dataset

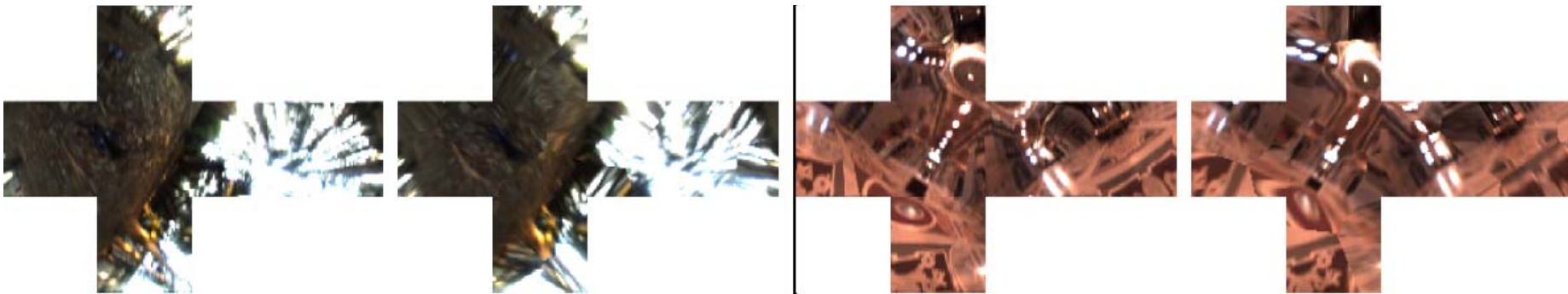


Transport Reconstruction Comparison

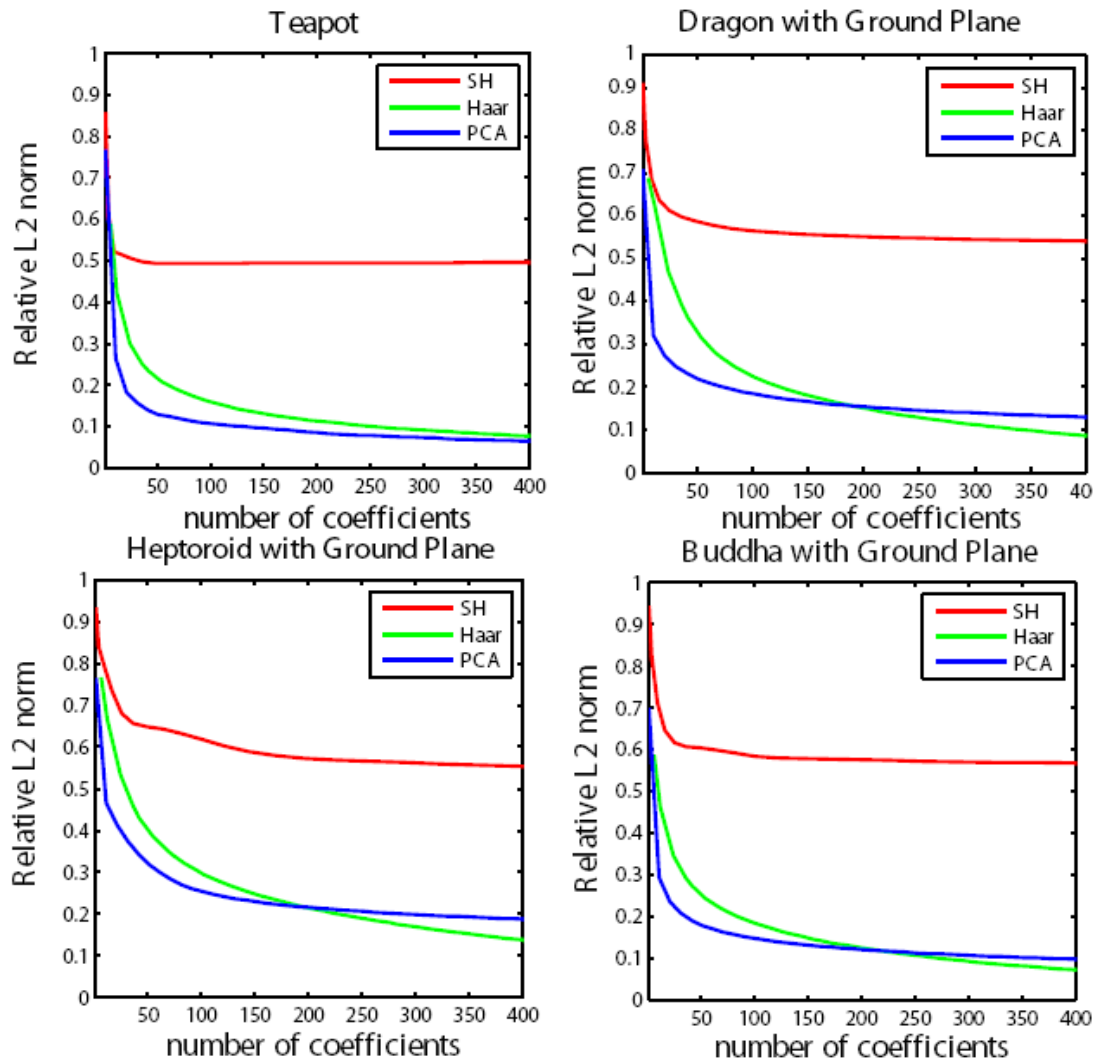


Rotating the Light

- Brute-force rotation can be slow since we have to resample the rotated lighting prior to projection
- Alternatively, we rotate our original sampling lattice and bilinearly interpolate from our originally sampled lighting
- This introduces a negligible error and is substantially faster



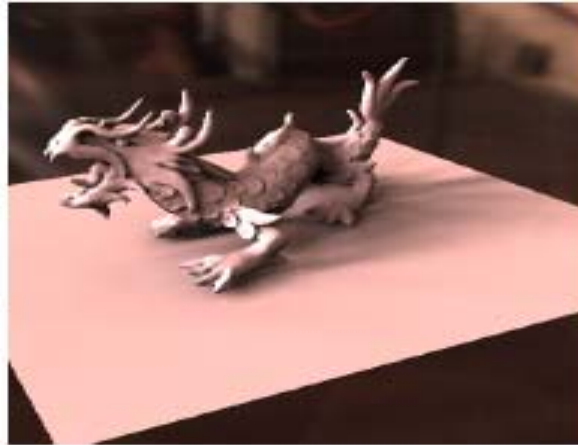
Numerical Comparison



Visual Comparison



(a) Ground Truth



(b) $d = 192$ (97.7%)



(c) $d = 96$ (96.1%)



(d) $d = 36$ (92.9%)



(e) $d = 12$ (86.32%)



(f) SH 36 Coefficients

Benefits of Eigentransport

- Seamless integration with current art pipelines
 - All you need is an off-the-shelf SVD algorithm
- For < 200 coefficients, better reconstruction error \rightarrow Suitable for games
- Simpler run-time algorithm than Haar
 - No coefficient thresholding

Conclusions

- Eigentransport can be integrated into current art pipelines
- Modest memory requirements
- Better reconstruction per coefficient for all-frequency shadow effects
- Fast run-time evaluation

Thank you! Questions?

