Sparse BRDF approximation using compressive sensing

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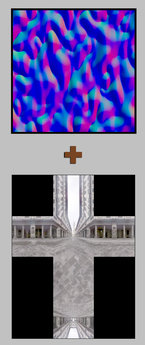
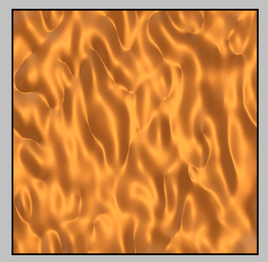
How much information do we need to reconstruct a BRDF ?

Overview



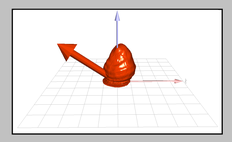


Synthetic input image

Take measurements and solve

$$x = argmin||Ax - y||_2^2 + \lambda|x|_1$$

where A is the measurement matrix,
x the BRDF representation
and y the vector of measurements



Reconstucted lobes

Context

BRDF acquisition is tedious (4D Data) : either explicit methods are difficult to setup and produce high volume Data, or acquisition methods based on parametric models reduce dimensionnality of BRDF space, with no guaranty that a given model can ever fit particular measurements.

Contribution

We experiment a new acquisition method from a single image, knowing the normals and illumination. We used synthetic input images (as a proof of concept) but we aim at using real data in the future.

Method

We work with isotropic BRDF, representing them into a fourier basis : Given an incoming angle θ_i, the lobe is expressed into spherical harmonics, and the coefficients are decomposed into cosines functions of θ_i:

$$\sum_k \sum_{l,m} a_{k,l,m} cos(\frac{k\theta_i}{n}) Y_l^m(\theta_o, \phi_o)$$

Then we solve a L_2 - L_1 problem to fit the coefficients with an input image.

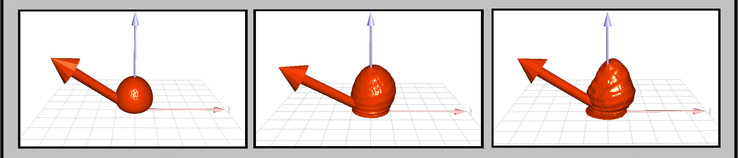
Compressive sensing

We use the SpaRSA algorithm to fit the BRDF. [Wright and al. 2009]
Starting from a random x_0, the method iterates :

$$x_{n+1} = S(x_n + \frac{1}{\alpha_n} A^T(y - Ax_n), \frac{\lambda}{\alpha_n}) \text{ with } \alpha_n = \frac{||Ax_n||_2^2}{||x_n||_2^2}$$

Where S, the is the soft-threshold operator. This algorithm finds the sparsest solution to the fitting problem.
λ is the sparsity weight. Most computation costs rely on the precomputation of the matrix A.

Control of sparsity



$\lambda = 10^{-2}$ $\lambda = 10^{-4}$ $\lambda = 10^{-6}$

From left to right : sparsity factor decreases, making the solution less sparse and getting closer to a classical gradient descent solution.

Results

Reconstructed material

Original Material

Reconstructed material

Original Material

We produced input images using real materials from MERL Database [Matusik and al. 2003]. Here blue-fabric and gold-paint are presented. Output images are produced using geometry from Stanford repository. Rendering with acquired BRDF is on the left and ground truth on the right.

Conclusion

Sparse reconstruction is possible with a moderate amount of input data.
Future work : glossy/specular BRDF.
Simultaneous acquisition of BRDF and normals

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