A Smooth, Fast, Accurate Representation of Reflectance

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The interaction of light with a surface is typically described by a bidirectional reflectance distribution function (BRDF). The BRDF, which represents all visible properties of the surface at the sub-textural level, is a function of (some parameterization of) incident and reflected directions.

We describe here a method to model any (especially measured) BRDF data by applying a modified form of the multilevel B-spline approximation ("MBA") algorithm presented by [Lee et al. 1997] to fit that data.

Previous Work

Many researchers have addressed the problem of representing BRDFs. We can generally classify their models as ad-hoc, physically-based, or data-driven. We will address the latter class here. Its members usually represent the BRDF as a weighted sum of basis functions, the most popular of which have included wavelets, orthogonal polynomials, and cosine lobes.

MBA does not require uniform sampling, allows arbitrary accuracy, is fast to compute and evaluate and, since it uses cubic B-splines, yields a C^2-continuous fit. The authors show how to merge MBA levels to replace a mesh hierarchy with a single mesh, making the evaluation time of the fit independent of resolution level.

Results

Selecting data for felt, leather, aluminum foil, and blue latex paint from publically-accessible databases, the fitting procedure was straightforward: Apply a three-dimensional (for an isotropic BRDF) instance of MBA to determine a set of coefficients.

Figure 1 shows accuracy results for several levels. For comparison, we chose the most accurate forms of the models of [Koenderink et al. 1996] (order 8) and [Lafortune et al. 1997] (3 cosine lobes). In all cases, our level 6 shows greater accuracy than the other two by a factor of at least 4, and usually an order of magnitude. Our level 4 has accuracy comparable to the other two models.

Figure 2 compares the fit evaluation times. Generally, basis function representations must increase the number of terms to obtain greater accuracy, thus leading to longer evaluation times. On the other hand, the time required for our MBA-based method doesn't increase with the accuracy of the fit: We always evaluate a $4 \times 4 \times 4$ submesh of the grid.

Conclusions and Future Work

Non-parametric, multi-level B-splines provide a smooth and fast BRDF representation. By increasing the size of the control lattice, MBA finds an arbitrarily good fit to the data. Other popular models are constrained by an accuracy vs. evaluation time tradeoff.

A drawback of MBA is the amount of storage required. While we have had some success (typically, a size reduction of 20:1) by splitting the fit into coarse, non-sparse "diffuse" and fine, sparse "specular" components, we continue to seek further reductions.

We also hope to use MBA's arbitrary dimensionality to extend this work to anisotropic surfaces, subsurface scattering, and texture representation and to implement this algorithm on programmable shading hardware.

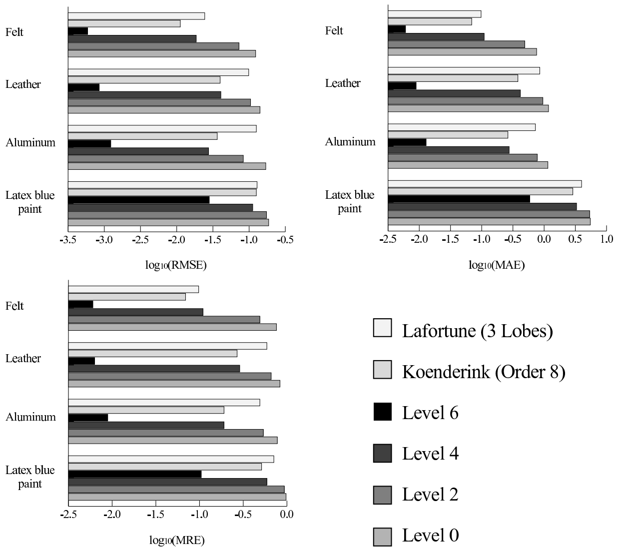

Figure 1: Accuracy Comparison. We use several error metrics: the root mean square error ("RMSE"), the maximum absolute error ("MAE"), and maximum relative error ("MRE").

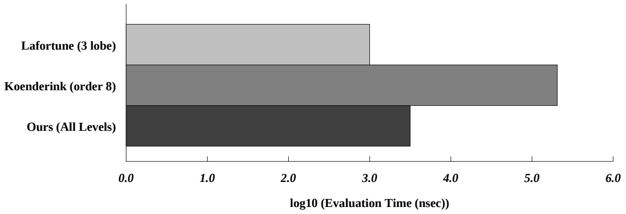

Figure 2: Fit Evaluation Time Comparison.

References

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