Fast Color-Space decomposition based Environment Matting

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Abstract

In the literature, environment matting (EM) refers to the complex process of discovering how light in an environment interacts with an object; notably, it may transfer through a transparent object, and undergo scattering. Modeling the 3D geometry, and the index of refraction, of non-uniformly optically active substances is intractable; therefore image-based frameworks are useful. The most convincing techniques use a large number of (monochrome, or two-tone) probing images to extract the matte.
In this paper, we provide an efficient EM technique, for purely refractive/reflective objects, which uses multiple colors as cues, and use a holistic color cube as the environment (instead of repeatedly solving the problem for five sidedrops and one backdrop.)

INTRODUCTION: It is fascinating to look at transparent objects exhibiting beautiful optical properties (see Figure 1). The breathtaking beauty emanates from the effects of refraction and reflection, often coupled with scattering effects. These effects are generated due to the interplay of the involved light matter interaction that occurs when light hits (or travels through the boundaries of) the transparent object.

RELATED WORK: [Zongker et al. 1999] develops a mathematical framework for modeling the optical effects of transparent objects, by analyzing several captured images of the object in front of hierarchical two-color patterned backdrops (and sidedrops). These techniques require *computationally intensive* non-linear optimizations. Alternatives [Peers and Dutre 2003] have been suggested, but at the cost of *additional images* (average date size of 2.5GB) [Chuang 2004].

OUR CONTRIBUTIONS: We provide an *efficient multiple-color* based EM technique. Specifically,

- For an output resolution of $k \times k$, our method *uses c colors and the color space decomposition approach* ([Boyer and Kak 1987]) resulting in a a small number ($\lceil \log_c k \rceil$) of captured input images.
- Unlike previous methods, for greater realism, we embed the object in a cubic environment map and therefore model all the sides *simultaneously*.

OUR APPROACH: Each pixel of the cube map may be "viewed" as a light source that may or may not impact the final image while interacting with the object. A naive way of finding the pixel of the cube map which contributes to the final image would be to illuminate one pixel of the cube map at a time. This results in too many images – equal to the total surface area. Instead we use color as a cue to differentiate various contributing pixels.

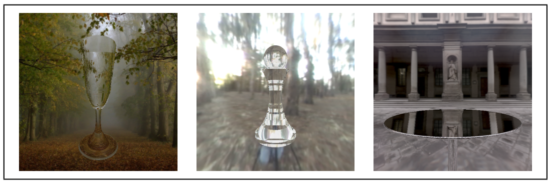

Figure 1: *A purely refractive wine glass, chess pawn; and a purely reflective table digitally composited in novel environments.*

The input to our algorithm is a set of (foreground) images of the scene, composed of the transparent object placed in *patterned* cube maps (aka background image). These images are used for creating a "mapping" between the (background) cube map and the (foreground) image pixels. This map is then utilized for compositing the object in a novel environment.

PATTERN GENERATION: The number of patterns required depends on the number of pixels in the cube map and the number of colors (c) used for coding them. The key idea is to use as many patterns as required to distinguish the (background) contributing pixels – this means that we code the possible pixels as a c-coded decimal (c = 2 corresponds to BCD).

MAP GENERATION: An observation relevant for purely refractive (or purely reflective) objects is that only one of the pixels in the environment, can reach a pixel in the foreground image. This is because the ray has to pass through both the (foreground) pixel and the camera pinhole. We can deterministically find this relationship because of the unique color code for each contributing pixel. Finding an exact match for the contributing pixel is of course not expected – a pixel using the least square measure can be found, however.

COMPOSITING: Given a novel environment cube map, for each foreground pixel of the new image to be composited, we look up the "map" for the contributing pixel in the cube map.

IMPLEMENTATION: For purpose of comparison with ground truth, we generated results for a *purely refractive wine glass, chess pawn* (index of refraction of 1.5), and a *purely reflective table* composited in novel environments (Figure 1). The correctness of our approach has been done by comparing our results to images of the same models rendered in the same novel environment using a standard rendering software, Persistence-of-View RayTracer. The images obtained are **exactly** the same as obtained using POV-Ray.

For a matte of size 512×512, we use 7 patterns and $c = 8$ colors. Typically, we require around 30 seconds to compute the matte and 4–7 seconds for compositing. All computations and timing calculations have been done with MATLAB on a Dual-Core AMD CPU with 2GB RAM.

References

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