Real-time Triangulation Matting using Passive Polarization

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Abstract

Blue screen matting separates foreground and background elements of video for special effects shots. It balances the benefit of real-time performance against the drawbacks of blue light spill throughout the scene. In this sketch we replace the traditional blue screen with a gray, polarized one, and film the scene with a single camera containing two differently-polarized sensors. For each frame, this camera simultaneously captures an image of the actor against an apparently black background and an apparently gray background. From these two images we can triangulate the foreground color and matte; this is an extension of a mathematically similar idea by Smith and Blinn that was previously applicable only to static scenes.

Our new method operates in real-time on video. It has comparable controls and setup to blue-screen matting, which is the de facto standard for practicality. Unlike blue-screen matting, our gray screen does not impact the illumination color of the scene.

1 Overview

Smith and Blinn's triangulation matting [1996] takes as input images I_0 and I_1 with the same center of projection but taken at different times with different known backgrounds B_0 and B_1. The compositing equations for these images are,

$$I_0 = \alpha F + (1-\alpha)B_0 \quad (1)$$
$$I_1 = \alpha F + (1-\alpha)B_1 \quad (2)$$

so the unknown foreground F and triangulated matte α are:

$$\alpha_T = (I_0 - I_1)/(B_0 - B_1) - 1 \quad (3)$$
$$\alpha_T F_T = I_0 - (1-\alpha_T)B_0. \quad (4)$$

Triangulation matting is well constrained (assuming $B_0 \neq B_1$ everywhere), produces high-quality mattes, and requires no user assistance, however it is only appropriate for static scenes. To pull triangulation mattes for video, we introduce a new capture system and background screen that are able to produce I_0 and I_1 simultaneously. We implemented alternative cameras designs (see Figure 1) that each contain two video sensors and a polarizing beam splitter, and created a polarized background screen using a common industrial laminate. For each frame, one sensor images a gray background and the other a black background. Because our screen is neutral-colored, it avoids the blue spill artifacts of blue-screen matting.

We use passive, natural (unpolarized, incoherent, unstructured) illumination from regular room fixtures, film set lights, indirect illumination, or even sunlight. This is in contrast to Ben-Ezra's related invisible key segmentation [2000] method, which illuminates the scene with polarized light and segments the image based on a polarized chroma-key algorithm. Our triangulation-based algorithm gives better sub-pixel results and our screen works with existing lighting infrastructure.

For robustness, we extend triangulation matting with a series of conservative luminance mattes and leverage the known relationship between B_0 and B_1 to completely eliminate the need for a priori known images of the background.

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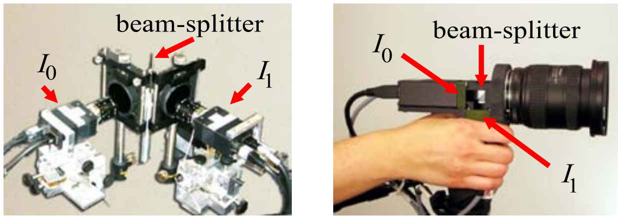

Figure 1: *Left*) Prototype camera that splits on polarization. *Right*) Hand-held form factor with the beam-splitter behind of the lens.

2 Results

Figure 2 compares our results for a hard test case to blue-screen, the competing method for unassisted, passive studio matting. Arrows point to several common matte artifacts that we avoid: (a) reflected blue light makes metallic and (b) mirror reflective objects disappear, as well as any (c) blue objects; (d) for Bayer-pattern digital cameras, blue-screen is limited to 1/2 or 1/4 of the input resolution, but working with luminance allows us to capture much more fine detail. Our method loses discrimination as the camera rolls about its optical axis towards 45° and is unable to mask flexible foreground objects the way a blue suit can for blue-screen.

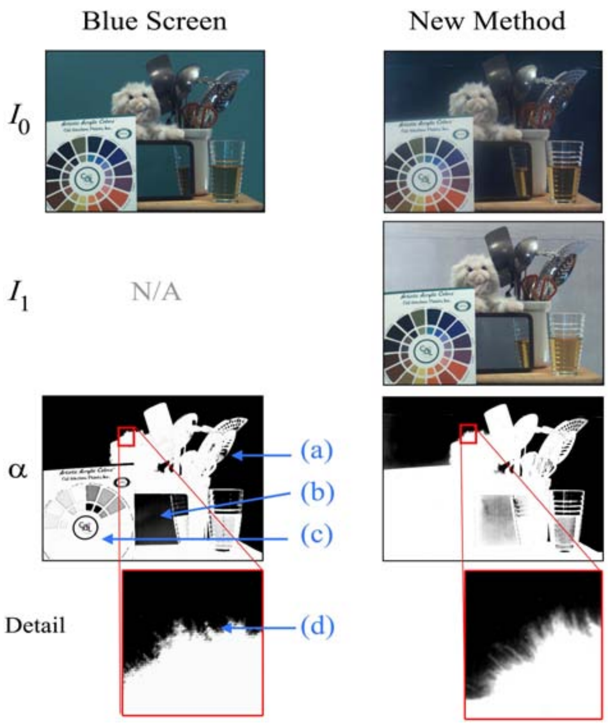

Figure 2: Comparison of blue(green)-screen and our method.

References

BEN-EZRA, M. 2000. Segmentation with invisible keying signal. In *IEEE CVPR*, 32–37.

SMITH, A. R., AND BLINN, J. F. 1996. Blue screen matting. In *SIGGRAPH '96*, ACM Press, 259–268.