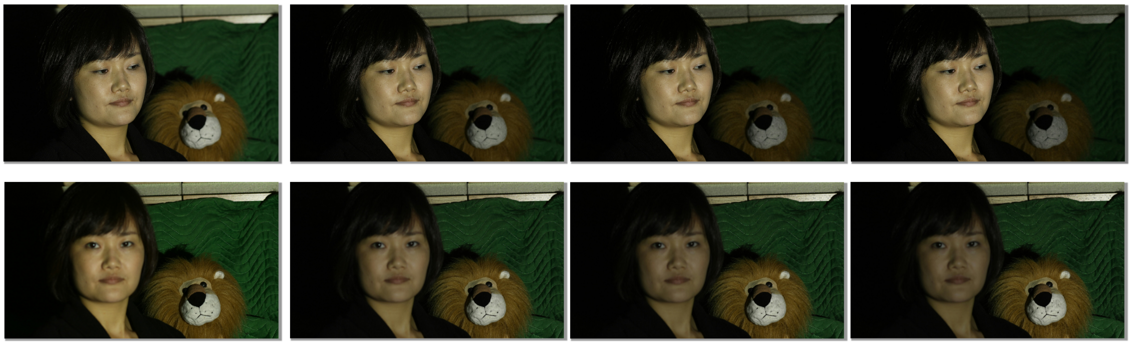
Highlighted DOF Photography: Shining Light on Focus



(a) Conventional Photo (b) Successive dimming of out of focus parts to highlight objects within the depth of field.

Figure 1: *Can we create photos where out of focus objects are not only blurred but also dimmed? Modern projector-as flash accessory may provide an opportunity for new focus related artistic effects. Top photos compare conventional photo and highlighted DOF photos generated by our methods when the woman is focused and the doll is out-of-focused. The doll is successively darkened from left to right while keeping the brightness of woman in our results. The bottom photos show comparison when the camera focus is opposite.*

Abstract

We present a photographic method to enhance intensity differences between objects at varying distances from the focal plane. Combining a unique capture procedure with simple image processing techniques, the detected brightness of an object is decreased proportional to its degree of misfocus. A camera-projector system is described to cast distinct grid patterns onto a scene to generate a spatial distribution of point reflections. These point reflections relay a relative measure of misfocus that is utilized in post-processing to generate a highlighted DOF photograph. Tradeoffs between three different projector-processing pairs are analyzed, and a model is developed to help describe a new intensity-dependent depth of field that is controlled by the pattern of illumination. Results are presented for a primary single snapshot design as well as a scanning method and a comparison method. As applications, automatic matting results are presented.

1 Introduction

A common technique in photography is to use the limited depth of field of a lens to emphasize and frame focused objects while de-emphasizing rest of the scene. Photographers use the largest F-numbers in portrait modes and invest in expensive lenses. Often simple blur is not sufficient for a composition goal. The goal of this research is to address some of these problems with a camera design that can decrease the brightness of out-of-focus objects resulting in a highlighted depth of field(HDOF) photo. In this work, we use a projector to display a spatial map of point patterns on a particular scene.

1.1 Contributions

We present an analysis of camera-projector setups that change the apparent brightness of objects based on their distance from the focal plane. Creating an intensity gradient along the z-dimension could be useful for object segmentation, contrast enhancement, or simply for creative effect. Included in this analysis is

- A geometric and physical optics model of misfocus for a projected grid pattern, which establishes a method to decrease the brightness of out-of-focus objects.
- Three unique projection-processing methods used to create HDOF photographs, including a single shot method, a two-shot method and a multi-shot method.
- Detail feature segmentation and object-selectable matting techniques are introduced as applications of the two-shot method.

1.2 Related work

Following is a brief overview of relevant imaging systems that use illumination to assist in the segmentation of depth information.

Scene Geometry and Structured Lighting: Investigations into using projected light to infer about a scene's geometry began with Will and Pennington [1971]. Since, projected patterns have found a wide array of applications in the estimation of 3D object shape [Salvi et al. 2004], [Mouaddabi et al. 1997], [Schechner et al. 2000], [Davis et al. 2005]. The wide application space for multiple images of shifted line or grid illumination extends to determining surface orientation [Maas 1992], [Wang et al. 1987], [Shrikhande and Stockman 1989], separating direct and global light components [Nayar et al. 2006] and to assist in robot mobility [LeMoigne and Waxman 1988]. While we use a projected array of points to highlight the plane of focus in this paper, the final goal is not to estimate complex scene characteristics. Instead, depth information is characterized by optical modulation of any portion of the scene that is not in sharp focus on the sensor.

Confocal Microscopy: The fundamental principle of a confocal microscope, which uses a pinhole to distinguish light from a particular depth, is very similar to our system. The confocal design has also been modified to use a more efficient array of microlenses [Eisner et al. 1998] or pinholes [Wilson et al. 1996], which we experimented with over our sensor. In general, larger pinholes lead to a larger depth of field and lower axial resolution in confocal designs. Following the same logic, we project small spots to better create a narrow depth of field around the focal plane. There has been recent work to incorporate light field imaging with confocal microscopy, as well as light field capture with a 4D illumination