Concave Surround Optics for Rapid Multiview Imaging, 2006

Concave Surround Optics for Rapid Multiview Imaging

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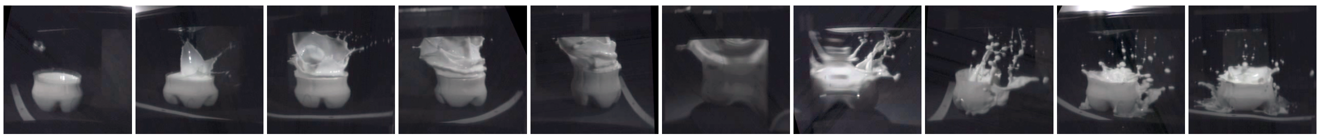

Figure 1: Rapid viewpoint change is shown in a high-speed video of splashing milk. The video was captured at 2000 frames per second with the stationary camera virtually rotating 360 degrees around the scene four times per second using the surround mirror system. Every 50th frame of the video is shown.

Many image-based computer graphics techniques involve photographing a subject from many different viewpoints. This is usually accomplished by moving the camera, moving the subject, or using an array of cameras. In this work, we use a system of mirrors to create the appearance of camera movement around the subject while both the camera and subject are fixed. Our first use of the system produces slow-motion video of a dynamic subject with smooth rotational camera motion during the event.

While high speed photography has long been used for the analysis of complex motions such as turbulent liquids, speeding bullets, and human movement, such video is typically restricted to a static viewpoint, limiting the sense of three-dimensional structure.

The simplest way to photographing a subject from many views is to rotate either the subject or camera, however this is not mechanically feasible at high-speeds. A second option is to interpolate between a large number of stationary cameras [Wilburn et al. 2005], however this adds significant system cost and complexity. Our solution is a single camera with an optical system of mirrors. Previously [Kuthirummal and Nayar 2006] have used a conical section mirror to photograph all sides of an object in a single wraparound image. However, the single image produced is not easily transformed to a series of perspective views of the subject. [Han and Perlin 2003] use a mirrored kaleidoscope to sample a hemisphere of incoming views and illumination. While this produces perspective images, the sampling directions are discretized.

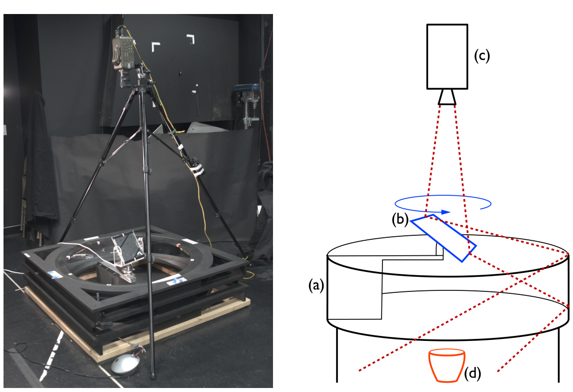

Figure 2: The setup consists of a (a) static cylindrical mirror, (b) flat spinning mirror tilted 35° up from vertical, (c) and a high speed video camera. The subject (d) sits directly below the center mirror.

Our system places a relatively large cylindrical mirror centered around the subject and a flat spinning mirror just above the subject (Fig. 2). The camera is placed in a stationary position above the scene looking into the flat mirror. The cylindrical mirror reflects light from the object onto the flat mirror which is angled to reflect this light up to the lens of the camera. As the flat mirror rotates about the vertical axis, it reflects different sections of the outer cylinder, producing a continuous series of virtual camera positions around the subject. The view of the subject also rotates in the 2D image plane and this motion needs to be removed in post-processing. Processed frames of a slow-motion milk splash filmed with a rapidly moving viewpoint are shown at the top of this page.

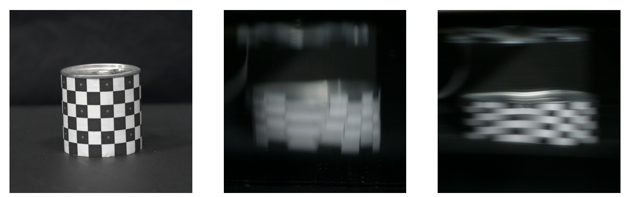

Figure 3: A cylindrical can (left) with a checkerboard pattern photographed at a wide f/stop demonstrates the differing focal distances of horizontal (center) and vertical (right) lines in the current system.

Images acquired with the system to date have two significant calibration issues. The raw images are horizontally stretched due to optical magnification by the curvature of the mirror; this magnification is removed by image scaling. The curvature of the mirror also creates a discrepancy in the focal distance at which vertical and horizontal lines appear sharp (Fig. 3). We currently solve this issue by using a small camera aperture to increase the overall depth of field. A more robust solution may be to use a rotating mirror with a slight curvature to negate the magnification of the cylindrical mirror. Our current cylindrical mirror introduces other distortions to the images. As it is inexpensively constructed from two mirrored Mylar strips held in shape by a wooden frame, the mirror seams introduce several visible mirror imperfections.

To demonstrate our system, we captured splashing milk at 2000 frames per second. Using the concave surround optics we are able to simulate a high-speed camera moving continuously around the event. Several viewpoint and time instances are shown in Figure 1. This video will be shown on a small LCD panel as part of the final poster display.

References

HAN, J. Y., AND PERLIN, K. 2003. Measuring bidirectional texture reflectance with a kaleidoscope. *ACM Transactions on Graphics 22*, 3 (July), 741–748.

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