Phyxel: Realistic Display using Physical Objects with High-speed Spatially Pixelated Lighting

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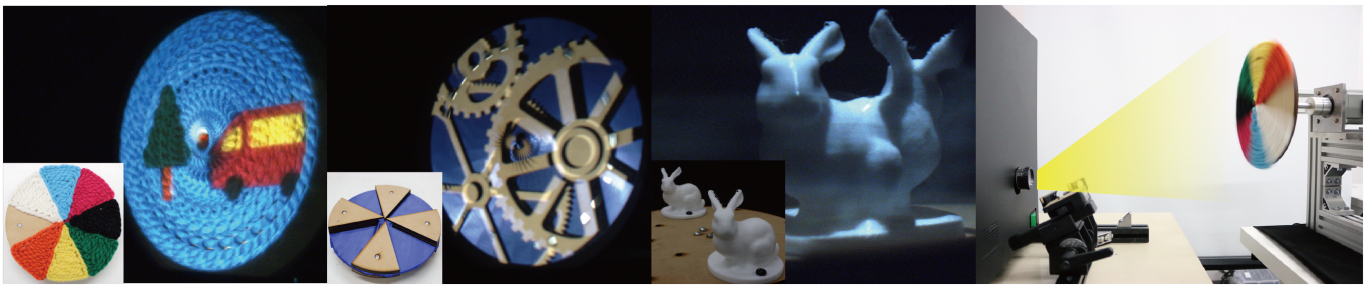

Figure 1: *Applications of Phyxel, a realistic display using physical objects. (a) Dynamic Stop Motion: an animated car passing in front of a tree in colorful wool display. (b) Layered 3D Display: rotating gears at different heights. (c) 3D Shape Mixture: a combined body with double heads from two 3D-printed bunnies. (d) Photograph of the developed system: a high-speed projector and a disk with physical objects.*

1 Introduction

Phyxel is a realistic display that makes a desired physical object appear at spatially pixelated locations. The created image appears to be essentially real and can be easily manipulated, like a virtual image. A promising approach to realizing this display can be found in some aspects of the Zoetrope or in Fukushima's work [Fukushima et al. 2015]. Toward the realization of Phyxel, it is essential to closely coordinate the lighting and motion for the perceptual reality. In the developed system, we manipulate the motion of various objects at high speed and control their perceived locations by projecting a computed lighting pattern using a 1000-fps 8-bit high-speed projector [Watanabe et al. 2015].

Keywords: 3D display, realistic reproduction, time multiplexing, persistence of vision, fabrication

Concepts: •**Computing methodologies** → *Mixed / augmented reality;* •**Hardware** → *Displays and imagers;*

2 Principle

Phyxel consists of a high-speed XGA projector and physical elements that undergo periodic motion (Fig.2). The physical elements are located on a rotating disk and pass through each pixelated position in real 3D space once every 33 ms. The projector is synchronized with the periodic motion and projects a designed lighting pattern within 4 μs when the target physical element arrives at the desired position, enabling relocation of the physical elements. A temporally-integrated light field can be identical to that of a real scene by repeating these operations faster than the persistence of vision. Therefore, a human perceives an image of a real object and feels like the object actually exists. At present, Phyxel can generate 200 mm $\times$ 200 mm $\times$ 50 mm images with max 32 objects at 1000-fps projection for 30-Hz perception.

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SIGGRAPH '16, July 24-28, 2016, Anaheim, CA,
ISBN: 978-1-4503-4372-5/16/07
DOI: http://dx.doi.org/10.1145/2929464.2929476

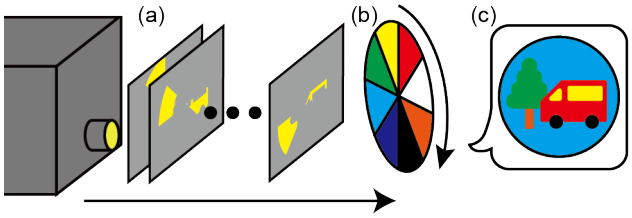

Figure 2: *System configuration: (a) adaptive lighting projection. (b) a rotating disk with physical materials. (c) temporal integrated image for human perception.*

3 Applications

We introduced three types of demonstration for the proposed system. First, Phyxel enables the creation of stop motion animation in real time and for naked eyes, since objects formed of arbitrary materials, such as wool, metal, oil-paint and so on, can be located at any positions (Fig.1a). This method is more favorable for making stop motion because conventional methods are labor-intensive and require post-processing for combining frames. Second, 3D shapes can be made by preparing layers at various heights along the optical axis of the projector. For example, embossed or cut-out pictures with dynamic motion can be achieved by using multiple layers (Fig.1b). Third, multiple 3D objects can be combined and relocated by adaptive lighting. Mixture of actual objects are achieved by cutting out parts in a cut-and-paste design and integrating them temporally (Fig.1c).

As a next plan, instead of the binary projection, we plan to control the brightness level in the projector for additional effects, such as motion blur and combining materials by taking account of color theory while keeping them physically consistent. Also, we believe that our system offers more sophisticated manipulation of real objects, and the improved degree of freedom in spatial arrangement will enable new types of real-world-oriented visual displays.

References

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