Swinging 3D Lamps: A Projection Technique to Convert a Static 2D Picture to 3D using Wiggle Stereoscopy

Nami Ogawa
The University of Tokyo
ogawa@cyber.t.u-tokyo.ac.jp

Takuji Narumi
The University of Tokyo
narumi@cyber.t.u-tokyo.ac.jp

Michitaka Hirose
The University of Tokyo
hirose@cyber.t.u-tokyo.ac.jp

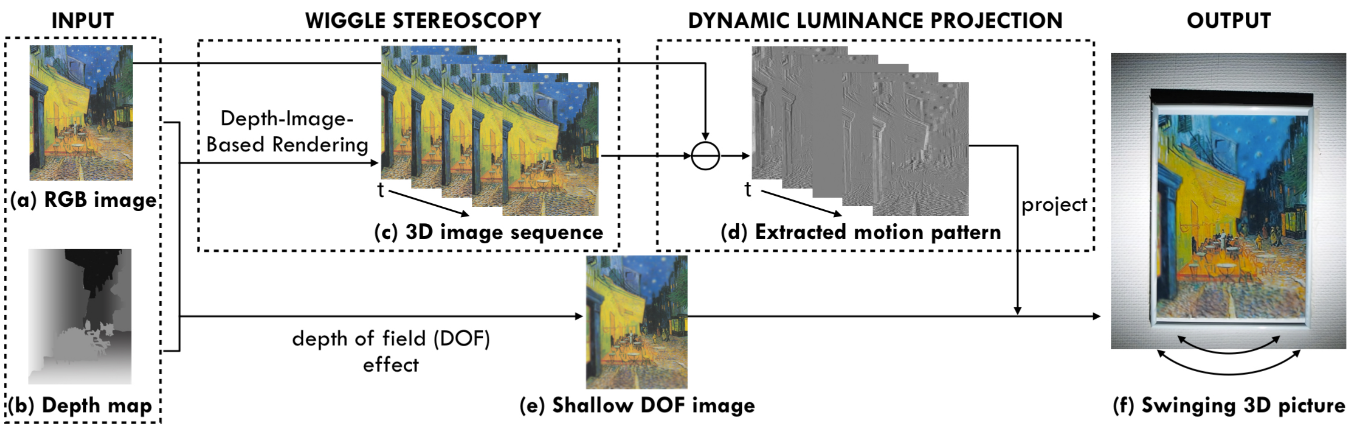

Figure 1: Flowchart of swinging 3D lamp technique to convert a static 2D image into a 3D image.

ABSTRACT

We present a multiuser, wide-angle, and naked-eye three-dimensional (3D) display technique called a "swinging 3D lamp." This technique creates 3D optical illusions of motion parallax by superimposing dynamic luminance patterns on a static two-dimensional (2D) image in a real environment. The basic idea involves combining "wiggle stereoscopy," a method of creating 3D images by exploiting motion parallax, with "dynamic luminance projection," a projection technique making static images dynamic. However, in some cases, it can be difficult to obtain sufficient depth information when combining these methods. This was overcome by adding a depth-of-field (DOF) effect on the original image. The proposed technique is useful for simple and eye-catching 3D displays in public spaces because of the fact that depth information can be presented on the RGB images of common printed media and that multiple people can perceive the depth without special glasses or equipment.

CCS CONCEPTS

•**Human-centered computing** → *Virtual reality;* Displays and imagers;

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KEYWORDS

3D, Projection, Spatial Augmented Reality, Wiggle Stereoscopy, Motion Parallax

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1 INTRODUCTION

Despite the development of 3D display technologies, large amounts of 2D printed or painted materials still exist that are typically unable to display in 3D. Current 3D display techniques suffer from limitations such as small viewing angles, distance from display, cumbersome or unsightly equipment, and high costs. These issues make 3D displays difficult to implement in everyday life. Herein, we present a multiuser, wide-angle, and naked-eye 3D display technique called a "swinging 3D lamp." This technique creates 3D optical illusions of motion parallax by superimposing dynamic luminance patterns on a static 2D image in a real environment. Our basic aim involves converting an RGB image into an RGBD image in a simple and clever way by combining the techniques of "wiggle stereoscopy" and "dynamic luminance projection."

1.1 Wiggle Stereoscopy

The technique known as "wiggle stereoscopy [Wikipedia 2017]" can be realized by rapidly alternating between stereoscopic pairs on common flat screens. Two images are sufficient to produce wiggle stereoscopy, but a smoother animation enabless a stronger depth perception effect. They offer a stereo-like depth perception effect by exploiting motion parallax, whereas most 3D displays are instead based on the principles of stereopsis that exploits binocular disparity. As motion parallax is one of the strongest monocular depth indicators, it requires no glasses, special equipment, or methods to operate, and its depth perception is independent of the viewing angle and distance.

Motion parallax 3D display techniques involving head-tracking and multiview 3D display techniques such as parallax barriers and lenticular sheets also produce similar motion parallax effects when the viewing direction changes. To perceive the depth using these methods, however, observers need to physically move and look around or change the angle of the display. In our method, because there is no requirement on the relative angle between the display and viewer, no effort is required by the viewer to perceive the depth. Moreover, head-tracking-type displays are normally limited to single-person use as the displayed information depends on the position of the observer. Using our method, multiple people can perceive the depth simultaneously. Lastly, it can be expensive to implement large multi-view 3D displays; however, our technique only requires a normal video projector and a printer.

1.2 Dynamic Luminance Projection

An additional technique we utilized is the "dynamic luminance projection." This makes static image perceptually dynamic by projecting only the dynamic luminance patterns introduced in "Deformation Lamps [Kawabe et al. 2016]". It is based on the characteristics of the human visual system (HVS) in that it binds the inputs of color, shape, and motion to render a coherent visual scene while automatically correcting small misalignments in the characteristics [Ramachandran 1987]. Dynamic luminance patterns are simply obtained by subtracting the image from its subtly deformed movie in every frame. Then, to provide the illusion of motion to observers, they are projected onto a static image, as shown in the technique of deformation lamps [Kawabe et al. 2016]. The technique does not reproduce the movements that originally existed in the deformed movie in a physically correct way but does produce a natural movie-like perception effect to human observers.

Although the deformation lamp is a technique that aims to add the impression of motion, our method aims to add the impression of depth. The combination with wiggle stereoscopy allows the semantic conversion of motion to depth and the conversion of a static 2D image into a 3D image in a simple manner.

2 SWINGING 3D LAMPS

By combining these two phenomena, swinging 3D lamps can realize the sudden change of a common normal static 2D image into a moving 3D image that provides the viewer with a surprise resembling magic. However, there are some difficulties when combining these two techniques. As motion capture is a type of illusion, the illusion collapses when the displacement amount of the original image deformation surpasses the visual angle by approximately $0.2 - 0.3°$ [Kawabe et al. 2016]. In contrast, a larger parallax of 3D image sequences can provide a stronger depth perception effect.

To address these issues and provide a sufficient depth perception effect, we exploited the characteristics of HVS. We found that the low-spatial-frequency components of an image are more easily integrated into motion information than high-frequency components. Thus, attenuating the high-frequency components in the area where the deformation displacement amount is relatively large enables the successful illusory integration of motion and static information while the total displacement amount is large; thus, it conveys a strong perception of depth. Considering that the displacement amount of each pixel in the motion pattern is solely determined by its depth value because objects that are located farther from the convergence point move faster than objects located closer, the substitution of shallow DOF images that have several low-frequency components in the out-of-focus area for the original image can work well. By inventing this method, we obtained a maximum amplitude of approximately $0.4 - 0.5°$ in visual angle.

2.1 system implementation

The parenthesized lower-case letters displayed below refer to those in Figure 1.

2.1.1 Making a 3D image sequence. First, we need to prepare the input comprising an (a) RGB image and its (b) depth map. Depth maps can be obtained manually, through manual drawing and stereo cameras, or by using computational estimation methods from the original image. In the case where we do not have a depth map but do have stereo pairs, these are sufficient for wiggle stereoscopy. However, by utilizing recent advances in computer vision, the depth maps can be obtained automatically from a single RGB image with a high precision for nearly all images.

Next, based on (a) and (b), the algorithm renders a (c) 3D image sequence using the Depth-Image-Based Rendering (DIBR) method [Fehn 2003]. This forms the basis for 3D viewing using the motion parallax effect. DIBR can be achieved by moving the pixel points of interest of a source image in accordance with its depth map. We interpolated the frames with 60 images because a smoother movement produces a stronger depth perception effect.

2.1.2 Extracting dynamic luminance patterns. Then, the system converts (a) and (c) into grayscale and subtracts (a) from (c) in every frame. The (d) extracted motion pattern is then generated.

2.1.3 Adding DOF effect to efficiently combine 2.1.1 and 2.1.2. At the same time, the algorithm generates a (e) shallow DOF image by adding a DOF effect. The DOF effect can be achieved by applying a Gaussian filter to the source image and changing the intensity according to (b), i.e., strongest intensity farthest from the focus point and weakest intensity nearest to the focus point.

Finally, the (f) swinging 3D picture is obtained by projecting (d) onto the printed (e) shallow DOF image.

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