Real-World Implementations of Visual Illusions by Using Augmented Reality Techniques

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ABSTRACT

Visual illusions refer to perceptual experiences wherein the appearance of objects and scenes is distorted. By taking advantage of the illusion which is often interpreted as undesired elements in perception, our technique can offer visual experiences which are not produced on the basis of the previous techniques.

1 INTRODUCTION

In general, we believe that we can perceive the correct appearance of objects and scenes. But, this may be a kind of misconception. Although the visual processing starts with the retinal stimulation by light, the spatial pattern of light array projected on the retina often distorts due to optical factors such as refraction, absorption, and scattering. Besides, because the retinal image of the light pattern is analyzed locally, the brain needs to integrate the output of the local image processing to get the global picture of the retinal image. In the integration process, some visual information is possibly lost, summarized, and abstracted. Therefore, the visual world we experience is not always the faithful reflection of the outer world. All we perceive is the illusory products by the brain.

Taking advantage of the properties of the visual system in the brain, it is also possible to manipulate the appearance of real objects in the scene. In particular, the usage of visual illusion enables us to express physically-impossible events in a perceptually possible manner. For example, our previous studies using a projection mapping technique called “Deformation Lamps” (“Hengento” in Japanese) showed that it is possible to give motion impressions to non-self-propelled static real objects though in the real world setting the non-self-propelled objects do not move. The Deformation lamps technique takes advantage of human motion detection system that is in general sensitive to luminance motion flow. Hence, the technique only projects luminance motion signals and gives a strong impression of motion to the real objects even with colored surfaces.

In a similar way, I propose two novel techniques to give the illusory perception to real objects: “Ukuzo” and “Danswing papers”.

2 Ukuzo: A technique to give shadow-based illusion to real objects

It is known that the appearance of an object can be altered by adding cast shadow patterns to it. In the graphical user interface (GUI) of the computer, icons and objects are often accompanied with cast shadow patterns which enhance the perception of the three-dimensional layout. Previous psychophysical studies have shown that the continuous change of the spatial distance between an object and its shadow can produce the illusion of the object’s motion in depth [2,3]. Artists also dexterously use cast shadow as well as shading to express the three-dimensional scenes. However, few attempts have been conducted to apparently change the three-dimensional layout of the real object.

I proposed an augmented reality technique to give the three-dimensional illusion to real objects by projecting a visual pattern that resembles the shadow of an object of interest via a video projector. Kawabe (2019) [4] proposed that by projecting a shadow pattern as shown in Fig.1f, it is possible to give the three-dimensional layout illusion as if a black puzzle piece in a printed material floats up over its original place (Figure 1h).

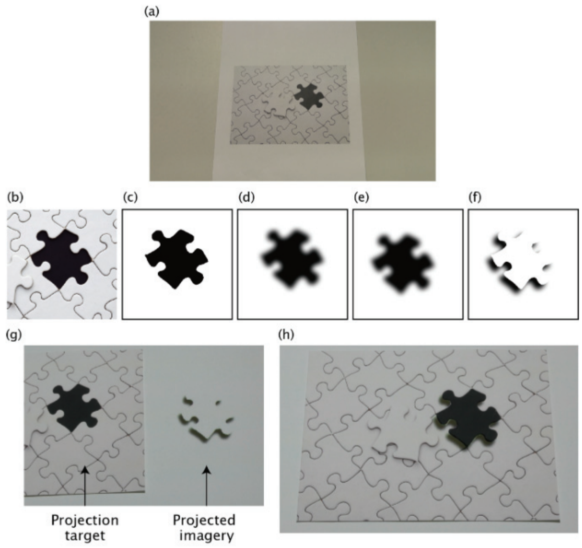

Fig. 1 (a) A projection target as used in Kawabe (2019). (b) A projection target image. (c) A binarized image of (b). (d) A blurred image of (c). (e) A spatially shifted image of (d). (f) A masked version of (f). (g) A projection target and the projected image of (f). (h) (g) is superimposed with the projection target, which generates an impression as if the black puzzle piece floats up over its original place. This figure was reproduced from Kawabe (2019).

In addition to an object in printed material, the technique by Kawabe [4] can give the three-dimensional layout illusion to a hand-drawn image. The system in the technique has a camera to capture the appearance of a projection target (Fig.2). By taking and manipulating the photo of the projection target, the technique generates a cast-shadow patter (see Figs. 1b-1f for the generation of cast shadow pattern from an image). Fig.3 shows the effect of the technique by Kawabe [4]. After the projection of an appropriate cast shadow pattern, it looks like as if the hand-written word “Reality”, as well as hand-drawn circles, apparently float up in the air over their original positions.

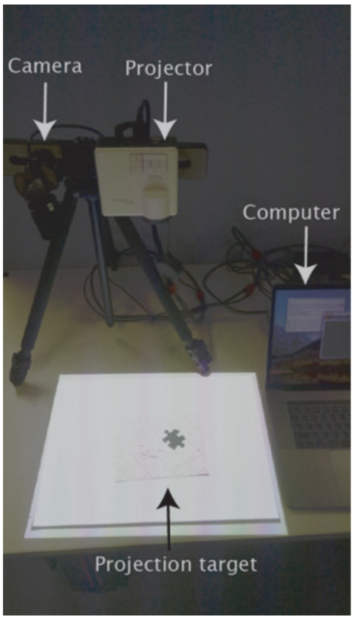

Fig.2 The photo of the system as used by Kawabe (2019) [4]. The image was reproduced from Kawabe (2019) [4].

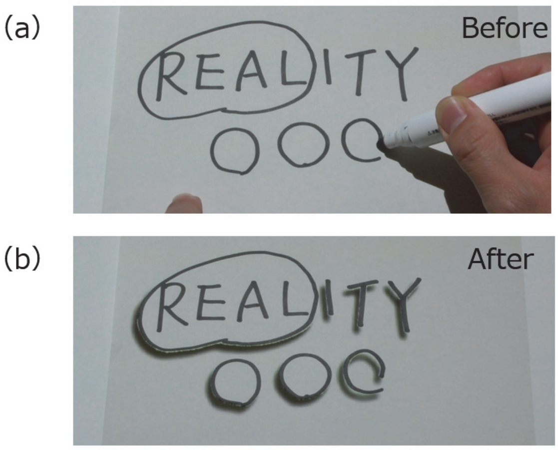

Fig.3 (a) A photo of the scene wherein a person is writing the word “REALITY” and additionally drawing some circles. (b) A photo of the visual effect of the technique by Kawabe [4].

In addition to the apparent three-dimensional layout, the technique proposed by Kawabe [4] can give transparency impressions to opaque printed material. Kawabe [4] tried to give transparency impressions to the printed material as shown in Fig.4a. Kawabe [4] demonstrated that when a cast shadow pattern was projected onto the black boundary of the horizontal stripe, the stripe apparently had the impression of transparent material as like glass or plastic while the vertical stripe remained opaque (Figure 4b). In contrast, when a cast shadow pattern was projected onto the black boundary of the vertical stripe, the stripe apparently had the transparent material impression while the horizontal stripe remained opaque (Figure 4c). When the cast shadow patterns were added to the boundaries of both stripes, both of the stripes apparently had the impression of transparency (Figure 4d). However, the cast shadow pattern inside the stripe was removed, the transparent impression was gone, and both stripes had the impression of opaque materials floating over their original positions (Figure 4e). These observations suggest that the spatial pattern of cast shadow pattern strongly modulates the transparent impression of a real object.

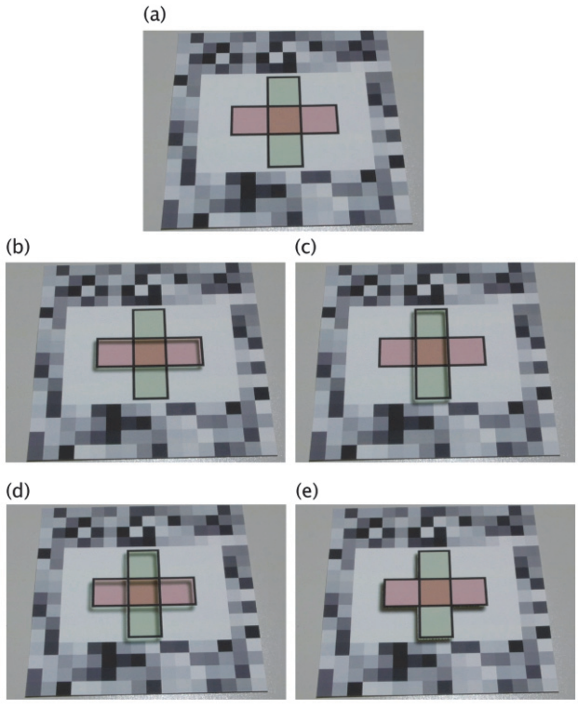

Fig.4 (a) A photo of a printed material depicting two overlapped stripes. (b) A cast shadow pattern is given to a horizontal stripe. (c) A cast shadow pattern is given to a vertical stripe. (d) Cast shadow patterns are given to both of the stripes. (e) Cast shadow patterns inside the stripe surface are removed. The image was reproduced from Kawabe (2019) [4].

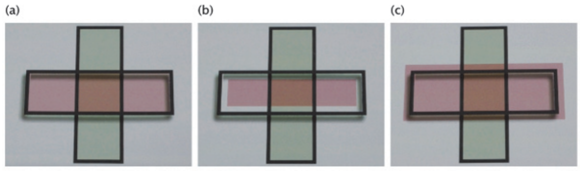

Fig. 5 (a) A transparency effect proposed by Kawabe [4]. (b)(c) When the boundary having cast shadow patterns is not spatially consistent with the colored surface region, no transparency impression of the stripe occurs.

Fig. 5 shows some examples wherein the spatial inconsistency between cast shadow patterns and surface abolishes the impression of transparency. This observation indicates that in order to cause the transparency effect, the cast shadow pattern needs to be projected accurately onto the boundaries that are spatially adjacent to the surface region.

3 Danswing papers

With the Deformation lamps [1], it is possible to give motion impressions to non-self-propelled static objects. On the other hand, to give motion impressions, we need a video projector. It is sometimes difficult to implement the video projector under everyday scenarios (i.e., at a supermarket and/or a station). Thus, it was necessary to come up with a new solution to give motion impressions to the static object without using a video projector.

Here I focused on the well-known illusion “phenomenal phenomena” [5] wherein a static rectangle in the CRT display apparently moves when the rectangle having the specific pattern of luminance boundaries is presented against a background with dynamic luminance modulation (Fig. 6).

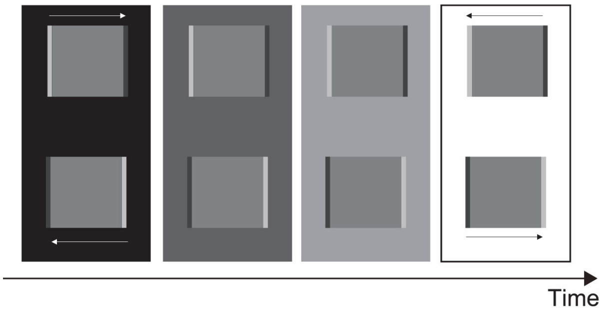

Fig.6 A schematic explanation of “phenomenal phenomena” [5]. Gray rectangles having luminance boundaries at their sides are presented against dynamic luminance modulation. In this situation, the rectangles apparently move in the direction of arrows in the figure. The figure was reproduced from Kawabe [6].

Kawabe [6] proposed a novel technique to give motion impressions to printed materials on the basis of the phenomenal phenomena illusion. In the technique, at first, the image of an object of interest is digitally created (here a gray heart object as shown in Fig.7). Second, black and white heart images are created. In Fig. 7, the black heart is spatially shifted rightward while the white heart is spatially shifted leftward. Third, the grey, black, and white hearts are synthesized so that the grey heart is placed at the layer in front of the other two hearts. In the synthesized image, the black and white boundaries appear along the boundary of the grey heart. Finally, the synthesized images are printed out and cut out to get the grey heart with black and white boundaries. When the cut-out object is placed onto the display (i.e., iPad) presenting the dynamic luminance modulation, the object apparently moves synchronously with the dynamic luminance modulation (see the YouTube movie of this technique: https://youtu.be/HVeCECoHwMw?t=9). Fig.8 shows the printed material of a crab to which the technique by Kawabe [6] is applied. As shown in the figure, the technique is independently applied to the body part of the crab and thus provides the impression of a dancing crab with observers.

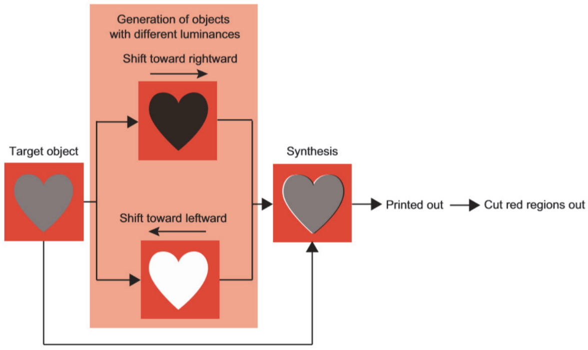

Fig.7 A schematic diagram of the pipeline of the technique proposed by Kawabe [6].

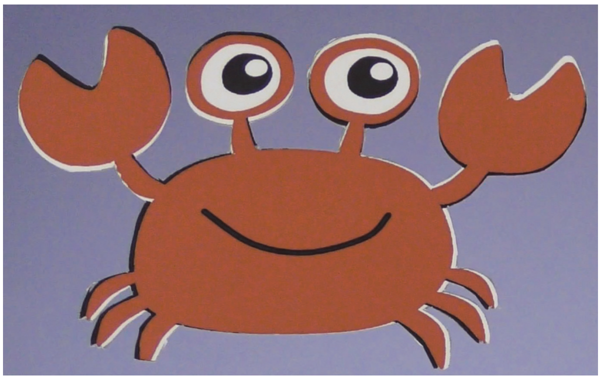

Fig.8 The photo of a crab to which the technique by Kawabe [6] is applied.

4 Conclusion

I proposed the two techniques to give unusual visual impressions to real objects. Ukuzo can add the three-dimensional impression as well as transparency impression to the two-dimensional, opaque printed material. Danswing papers can add motion impressions to printed materials without a video projector (but with the LCD presenting dynamic luminance modulation).

These techniques can be applied for enhancing visual communications in the real-world setting. For example, Ukuzo can be used to emphasize the depth and transparency impression of the objects in paper-based posters that are put on the wall at the supermarket and/or the station. Danswing papers can also be used to emphasize the logo mark of a product/company by adding motion impressions to it. Thus, the techniques utilizing visual illusions can make the visual world richer and more informative. Although it is necessary to pay attention to the negative side of the effect of visual illusions, I believe it is in principle a promising strategy to implement visual illusions to the real world in the future information presentation techniques.

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