New integral imaging technique uses projector

Makoto Okui, Jun Arai, and Fumio Okano

Using a new screen structure, it is possible to reproduce 3D images by either front or rear projection.

Integral imaging is highly effective at allowing observers to see 3D images without special glasses. Based on integral photography, an idea first introduced in 1908, more recent research in this area has been centered on electronic media applications such as 3D television. However, integral imaging systems are still at an early stage of development: in many cases, a direct-view liquid-crystal display (LCD) panel is used as the display device. If integral imaging can be made to work in a projector (PJ)-based display instead, this will have several advantages. First, the PJ can be used to project images onto a large screen. Second, this kind of system consists of both a projector and a screen: the two-part structure is more flexible than one designed for direct view. Third, given this flexibility, we can use either rear projection or front projection, for instance, to display ordinary 2D images. Finally, we can use multi-projection: several PJs can be lined up side by side to project images onto the screen to increase image resolution and the area of display. These advantages have meant that PJ-based systems are now commonly studied for application to integral imaging.

Figure 1 shows a typical direct-view arrangement. Tiny elemental images that come from many viewpoints are formed on the display screen. Light rays from these then converge through the lens array to form the 3D image. Based on this idea, we have come up with a design compatible with a projector-based approach. One main difference is the screen: it does not have a diffusion layer, but instead consists of lenses. There are several variations of this design, with Figure 2 showing an example with a rear-projection arrangement. This structure offers two functions. One is the formation of a viewing zone by convex lenses $L_A$ and $L_B$, and the other the formation of elemental images by two lens arrays $EL_A$ and $EL_B$.

The lenses $L_A$ and $L_B$ take light beams from a projector and let them converge in the viewing zone, at the same time ensuring in-zone brightness. The conventional method for achieving this is to use a diffusion screen that produces several viewing zones, including some that are not necessary. By this method, which uses lenses instead of a diffuser, only the correct viewing zone is formed—correct in the sense of geometrical reproducibility. This function also improves the efficient use of available light.

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Of the two lens arrays, the second one (EL₂) functions just like the elemental images in integral imaging. These elemental images are formed on the corresponding individual lenses of the first array EL₁. In this way, the light rays of these elemental images are efficiently led to corresponding elemental lenses, reducing unnecessary crosstalk with adjacent lenses.

There are many other possible variations of the design shown in Figure 2: for instance, the projector can be set diagonally from the screen. With a proper offset, the relationship between the two lens arrays shifts by an element, positioning each elemental lens to receive the adjacent elemental image. As a result, the viewing zone is also formed at an offset position. As the arrangement in Figure 2 is horizontally symmetrical, a mirror can be inserted between the two lens arrays to turn it into a reflection design, in which a projector can be placed on the same side as the observer. These two ideas are combined in Figure 3.

Experimental results for these two arrangements are shown in Figure 4 (a, b). We can see that Figure 4 exhibits the characteristics of integral imaging, i.e., reproduction of an image with full parallax.

Here we have reported on a new type of screen for integral imaging. The technique described can be used not only to increase the variation in integral imaging applications, but also to improve resolution and viewing zone through the use of several projectors. Further, installation space can be used more flexibly as either rear or front projectors can be used. For instance,

**Figure 4.** Experiment results. (a) Image produced via rear projection: the arrangement shown in Figure 2. (b) Reproduced image by front projection, based on on a modified version of the Figure 3 arrangement. Partial distortion is due to experimental limitations.

...a screen can be hung on the wall or set flat on a table with the PJ installed diagonally above.

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**Author Information**

**Makoto Okui**
Universal Media Research Center
National Institute of Information and Communications Technology
Tokyo, Japan
http://www.nict.go.jp

Dr Makoto Okui was with NHK Science and Technical Research Laboratories until 2006, when he moved to the National Institute of Information and Communications Technology. He is currently leads the 3D Spatial Imaging and Sound Group.

**Jun Arai and Fumio Okano**
Science and Technical Research Laboratories
NHK (Japan Broadcasting Corporation)
Tokyo, Japan

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Dr Jun Arai is research engineer in NHK Science and Technical laboratories. His research interests include optoelectronics systems and three-dimensional television systems.

Dr Fumio Okano is an executive research engineer in the NHK Science and Technical research laboratories. His research interests are optoelectronics systems including cameras and displays and three-dimensional television systems.

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