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3-D TV

Attempts to produce stereoscopic perception of depth in images have been recorded since at least the mid-19th century. ***Stereopsis*** is the impression of depth that arises when humans and other animals view the world using two eyes. Since each eye is at a slightly different location with respect to any object in a viewed scene, the brain can use the difference between the left and right eye images to extract information about depth (and, thus, perceived three dimensionality). Stereopsis was first described in detail by Charles Wheatstone in the 1830s (although it had been observed but not properly understood during the Italian Renaissance).

A variety of devices, usually termed ***stereoscopes***, were constructed during the Victorian era which presented viewers with slightly different images to the left and right eyes (usually by projecting them through lenses into each eye separately).

Anaglyphic 3-D

The rise of modern cinema saw several additional attempts to convey stereoscopic information to the big screen. The most popular of these, at its peak in the 1950s and 60s, was ***anaglyphic*** projection (**Fig. TF28-1(a)**). Viewers watching a projected movie (or television screen) wore glasses with different color filters in front of each eye (usually cyan and red). Two images were projected simultaneously on the screen, such that only one image could pass each filter and be perceived by the eye. Since each of the two images or films had been captured by cameras slightly offset from each other (to mimic the separation of human eyes), the brain stitched these images together somewhat naturally and perceived depth and "3-D" in the film. Anaglyphic technologies suffer somewhat in that they do not provide perfect color reconstruction and can often produce blurry or ghost images (depending on the quality of the filters used).

The New Rise of 3-D TV

The rapid maturation of flat-screen television, leading to very high resolution, very fast refresh times, high contrast ratios and deep color reproduction, enabled a new resurgence in 3-D technologies in the last few years. Several technologies are currently competing for market dominance (with others in development).

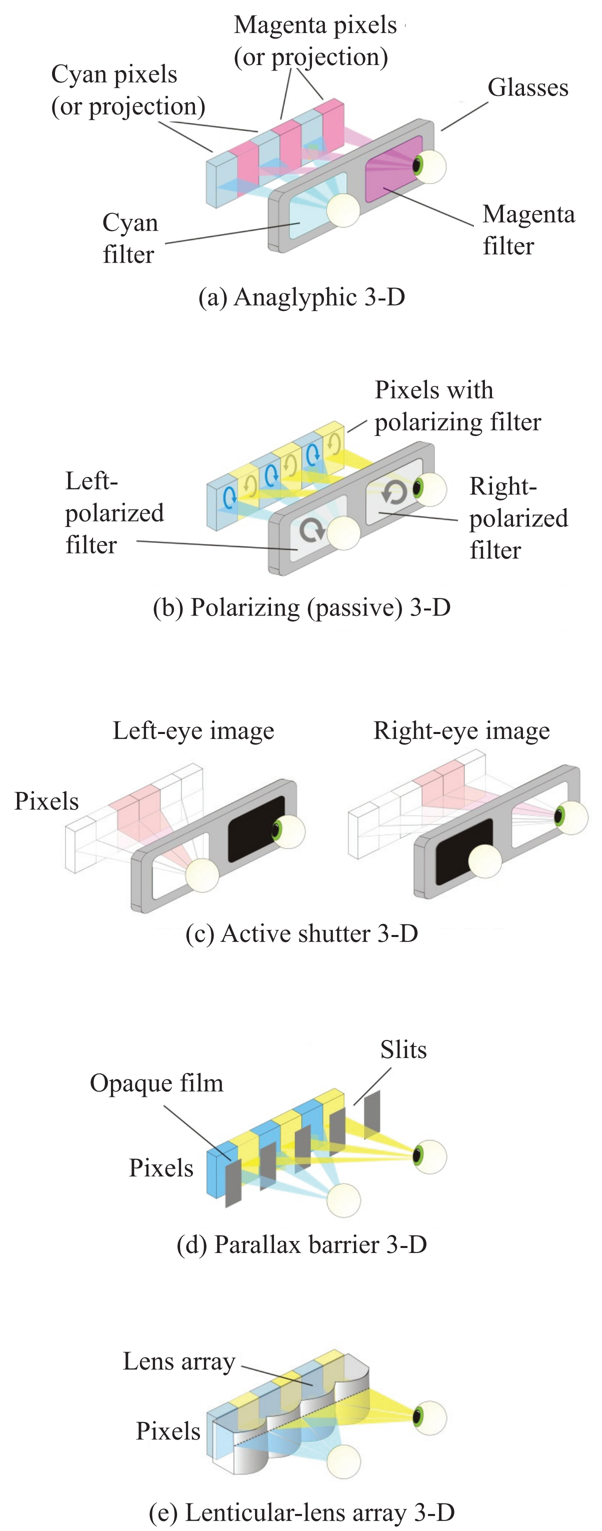

Figure TF28-1: Various techniques for realizing 3-D imaging.

Polarizing 3-D

So-called ***polarizing*** or ***passive*** 3-D TV is in some ways similar to anaglyphic systems. Instead of employing color filters, 3-D passive TV glasses use ***light polarization*** to deliver different images to the left and right eye (**Fig. TF28-1(b)**). Light is, of course, electromagnetic radiation perceived by the human eye. Traveling waves of electromagentic radiation are composed of oscillating electric and magnetic fields with specific orientations or ***polarizations*** (this does not refer to the direction of travel of the light, but rather, the directions in which the light's electric and magnetic fields oscillate as the wave travels through space). The details of light polarization can be complex, but of importance to us is the fact that polarizations can be complementary; for example, light can travel with clockwise polarity or counter-clockwise polarity with respect to its source. The human eye cannot tell the difference between different polarizations of light.

Passive 3-D television sets contain polarizing filters placed in front of the pixels in the display; with these filters, half of the pixels in the television emit clockwise polarized light and the other half produce counterclockwise polarized light. The viewer wears glasses which let only one polarity of light through to the left eye and the other to the right eye. In this way, each eye is presented with a different image. This type of 3-D TV has advantages in that the glasses are very lightweight. Historically, the main drawback of 3-D images was the decrease in resolution of the image (since each eye received half of the total pixels of the television). Recent advances, however, may be solving this problem. One approach, made possible by the speed of modern pixels, is to present each eye with half of each full-resolution stereoscopic image (as above) and then, *very quickly*, present the eyes with the other half of a full resolution image. This requires televisions that can refresh images at 120 Hz (120 times each second or a new image every 8.3 milliseconds); this is about double the speed at which a human eye can perceive flicker!

Active Shutter 3-D

Active shutter 3-D or ***alternate frame-sequencing 3-D*** sets also use glasses but they tend to be heavier and more expensive (**Fig. TF28-1(c)**). This type of technology uses a normal flat-screen TV (but it must be fast) to display the images intended for the left eye alternating in time with the images intended for the right eye. In other words, while watching a movie, the television displays a frame intended for the left eye followed by a frame intended for the right eye, and so on. The glasses hold LCD screens over each eye and receive a synchronization signal from the television (either infrared or radio frequency). In sync with the TV, the glasses block light to the left eye (by darkening the LCD), then block light to the right eye, and so on, repeating this sequence 24 times a second or faster. In this way, each eye receives the stereoscopic pair intended for it at full resolution. Unlike traditional passive 3-D TVs, all pixels are used for each frame of the image.

Parallax Barrier 3-D

Parallax-barrier displays are a ***glasses-free*** 3-D display technology that has been around for a number of years but is beginning to make it into prototype flat-panel televisions. Parallax-barrier technology was used in the Nintendo 3-DS hand-held and several 3-D smartphones. The idea behind parallax barrier technology is shown in **Fig. TF28-1(d)**. An opaque film with precisely aligned slots is fabricated over the display pixels; the slots are intended to block light from some pixels from reaching the left eye and to block light from other pixels from reaching the right eye for a viewer standing directly in front of the display. The principal advantage of parallax-barrier displays is that no glasses are needed; anyone standing in front of the TV sees images in stereoscopic 3-D. The two principal disadvantages are the halved resolution (similar to traditional passive 3-D, as explained above), since light from only about half the pixels reach each eye, and the limited viewing angle for 3-D. Typical prototypes only work within a 20° angle on either side of center, making it less attractive for consumer use (although the technology is evolving fast).

Lenticular-Lens Arrays

Lenticular-lens arrays (**Fig. TF28-1(e)**) work in a similar manner to parallax viewing except that the light from a given pixel is *focused* onto the right or left eyes (as opposed to blocked) by an array of precisely fabricated lenses (a very thin plastic sheet is usually molded into a regular array of lenses) sitting over the display. Lenticular-lens displays currently suffer from similar drawbacks to parallax-barrier displays and are currently very expensive. As with parallax-barrier technology, several companies are actively pursuing this technology and prices may drop rapidly as the technology matures.