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Displays with Depth

Polarization technology makes 3D almost painless

A 3D driving game facilitated by a ColorLink polarization projection display system.

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The process of simulating 3D from 2D sources has always been one of illusion and compromise, and that hasn't changed a great deal as science has progressed since the first 3D imaging of 1838. The earliest systems provided the stereoscopic illusion by using two images taken from slightly different perspectives to mimic what binocular vision provides the human eye in real time. Each image was then exclusively presented to the appropriate eye using a stereoscope that isolated each eye's filed of view and adjusted the focal point of the images. The View-Master of the 1940s provides a more contemporary example of this technique in action. A similar effect can be obtained without the stereoscope by using cross-eyed or divergent viewing, but with greater eyestrain and distraction for the viewer.

A somewhat more open and accessible approach based on the same concept involves anaglyph images, where the two offset images used previously are each run through a different color filter (red-blue, for example) and then projected on top of each other. This is then viewed wearing glasses that contain a red filter over one eye and a blue filter over the other, with the brain being appropriately confused into the perception of depth with the merged image. Anaglyph images allowed the use of simple glasses instead of a rigid viewing device, and opened 3D imaging up to more leisurely viewing environments such as a movie theater.

An alternative but similar 3D technology that dates back to about the late 1920s involves offset images filtered with different linear or circular polarized light instead of color. While this technology does not deliver the dream of unassisted 3D viewing it does provide a high degree of depth, color and resolution performance with an acceptable eyewear-based form factor. Although various companies such as Phillips

are exploring eyewear-free 3D using pixel-by-pixel lens systems, cost, resolution and viewer positioning issues will likely be limiters for some time to come in many applications.

ALTERNATIVE POLARIZATION PATHS

There are a variety of different functional ways to generate a polarization-based 3D effect.

Most light is unpolarized, with the light waves vibrating in many planes. Fliters can be used to polarize the light linearly across a specific axis by only allowing waves through on that axis—for example on a 90° vertical or horizontal plane. An additional quarter-wave retardation plate can be added to phase shift the polarized light 45° causing the light to rotate left or right in time, creating circular polarized light.

To obtain the 3D effect, two slightly offset images are again used and projected on top of each other, with each image being differently polarized. Polarized glasses with a correspondingly different filter for each eye then help the brain create the 3D depth effect.

It should be noted that this is differentiated from the polarization approach using LCD shutter glasses, where a display will rapidly present appropriate sequential left eye and right eye images. The LCD shutter glasses, which are synchronized to the display, then alternately black out in sequence the inappropriate eye for the presented image. While functional, this approach can be costly where mass viewing is desirable and it can create some adverse physical reactions from flicker, similar to those with lower refresh rate settings on CRTs.

A boon to polarization 3D has been the LCD monitor, which emits polarized light. A variety of companies have developed different approaches using this technology to create a 3D effect.

3D ENTERTAINMENT

ColorLink (Boulder, Colo.) has a progressive focus on bringing 3D to the masses, with the initial approach focusing on polarized light. A big issue with entertainment applications is content—which creates a chicken and egg scenario. It's hard to justify purchasing a 3D system if there is no content available, and it's equally hard to justify 3D content creation if there is no infrastructure in place to support that content. Fortunately, both aspects are converging today.

The Planar dual monitor 3D display system.

"'Chicken Little,' 'Monster House,' 'Meet the Robinsons' and the upcoming 'Nightmare before Christmas' are all 3D-enabled movies that use polarized light as a platform," said John Korah, ColorLink's technical marketing manager. "These are coming from large movie houses (Walt Disney Pictures and Columbia Pictures), and cinema is starting a trend that migrates into the house. The problem today is that CRT is still the prominent display in the market even though new sales may be eroding to LCDs and plasma and projection. It will be at least five years before this changes significantly."

However Korah noted that trend is certainly happening much faster with PC monitors, and that 3D gaming and DVD playback on the PC platform has already arrived.

ColorLink is demonstrating a PC-based gaming system using dual projectors which provide circular polarized light. The light coming out of one projector is encoded in left circular polarized light and the light from the second is encoded with right circular polarization, and they are projected on top of each other on a screen. A driver sitting in front of the screen can then take part in a virtual 3D race through the streets wearing a pair of appropriately filtered glasses.

With linear, and to some extent narrowband circular polarized light, tilting the head outside of the optimum viewing angle can lead to crosstalk that results in image distortion and the loss of the 3D effect. ColorLink has technology that allows super broadband circular performance which provides circular in the blue, cyan, green, yellow and red with a much wider effective viewing area.

Another approach used by ColorLink involves ALPS, its Achromatic Linear Polarization Switch. ALPS allows the use of the single, fast-drivable projector instead of two projectors. The device sits outside of the projector lens and sequentially converts information that is falling on it into a customer defined polarization state which can be linear polarization or circular polarization. Depending upon the quarter wave plate that is selected, the result can be ei-

ther a narrowband circular, broadband circular or achromatic circular sequential light.

An additional option being developed applies to direct view LCD displays, where a filter film is added to a standard LCD monitor with one row of pixels being plus 45° circular polarized light and the other row being minus 45° circular polarized light that alternates across the entire display. There is not necessarily any loss in transmission brightness and the quarter wave film does not necessarily eat up the light. Appropriate glasses allow each row of pixels through to the appropriate eye. The monitor can be toggled between 3D and 2D output based on the content and the monitor works as a perfectly normal high quality 2D display when not used as a 3D monitor.

The use of different polarization approaches becomes one of cost and application requirements. "While achromatic circular might be the preferred solution from a performance and quality standpoint, cost savings are provided with simpler solutions that may be adequate for the required task," said Korah. "A full capability achromatic solution involves an additional multi-layered filter to the polarizer which adds cost. Low-volume but high performance application requirements, such as scientific medical visualization, would typically demand achromatic solutions. Similarly, a high-end gaming emporium may require the highest quality to support its business model. In a cinema, image quality and performance are balanced by the price of eyewear, and in that circumstance the solution might involve a narrowband or perhaps a broadband quarter wave solution. Linear polarization does not require a quarter-wave plate and the cost that goes with that addition. A linear approach may be appropriate for theme park where the volume of glasses used is exceptionally high and disposable eyewear might be the solution."

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With an eye towards the future, ColorLink is working with leading projection television suppliers to lay the foundation for future 3DTV. The goal is to have a perfect 2D television set capable of handling 3D content as needed.

"ColorComb™, using 3D separations based on color, hearkens back to the old anaglyphic 3D with a twist," said Korah. "Our approach is to break a red green and blue up into two types of each color, and then take one red, one green and one blue and transmit it to one eye while you take the other red green and blue and transmit them to the other eye. The goal is to maintain the neutrality of the colors between the eyes yet still allow the transmission of different information each eye. This fits the direction in which LCDs and projection televisions are heading, which is moving away from the UHP (Ultra High Pressure) lamp sources to LED or laser based systems which are narrowband spectra and promote two versions of each color.

Korah noted that television manufacturers are already moving towards extended color gamuts, and that such a television would offer enhanced 2D performance while being fully capable of effective 3D display by pushing a button and putting on the appropriate eyewear. Such a solution could be ready in several years, and be perfectly capable of providing an enhanced 2D image (without a notable increase in cost) while waiting for 3D content to catch up with the hardware.

PUMPING UP THE RESOLUTION

Planar Systems Inc. (Beaverton, Ore.) provides 3D polarized light LCD solutions in SXGA resolution at 17", UXGA resolution at 20" and a 23" monitor with the Wide UXGA pixel format. Providing the left eye and right eye images is accomplished in a fairly unique way using two monitors and a "StereoMirror" approach making use of a half-mirror similar to that found in heads-up displays.

"Using our display is like looking at a regular active matrix LCD with sunglasses on," said Pat Green, Planar's director, Technology Group. "There is no flicker issue; you do not get a sense of unease due to unrealistic visual cues unless it's in the image to begin with, of course. Planar's StereoMirror allows the full resolution with both eyes and no compromise."

An upper monitor reflects off of a mirror, superimposing its image over the second monitor which sits vertically in a normal manner. "The video signal to the upper monitor needs to be flipped because of the reflection," said Green. "A card is provided that goes into a PCI bus with the Xilinx FPGA that does a line store and reads the line out backwards to do the mirror flip. We're working to integrate that function into the monitor itself and eliminate the additional card."

The company's patented process relies on a 50 percent transmission, 50 percent reflection mirror. The lower display is presented in transmission as it travels through the mirrored surface, with the light polarized but with no change to the plane of polarization. With the upper display, the light is reflected off of the mirror and the plane of polarization rotates 90°. Appropriate polarization filters on the glasses allow the left eye to view the image from the lower monitor and the right eye to view the image from the upper monitor. The exclusion stereo contrast approaches 200 to 1. The Planar StereoMirror design can be applied to almost any active-matrix LCD display.

"Our approach is highly suitable for the geospatial analysis market, computational chemistry and drug discovery and medicine," said Green. "In some markets, such as geospatial, you don't have to convince people that 3D is a good thing. However, there are a number of people who have tried stereo displays in the past, and because of the discomfort or the set up issues at the time they have developed what I would call 'stereo fatigue.' We've been very successful in converting a fair number of these folks once they see our display at work."

In medical imaging applications, Green noted that an ongoing study at Emory University has already found a significant reduction in the level of false positives that otherwise would have resulted in callbacks to patients. The technology also promises to revolutionize some surgical procedures. "Minimally invasive surgery is a hot topic and a win for both the patient and the insurance company," he said. "The challenge for the surgeon is that currently most of these procedures are done monoscopically. We have shown our monitor to several physicians using different stereoscopic probe designs with excellent feedback."

As with ColorLink, Planar has an appreciation for future entertainment applications. "The biggest market for stereo 3D products is 3D games," Green said. "Today, our focus is on professional users but we're certainly examining this arena as an option."

Dual projectors provide the appropriate polarization imagery for each eye with this approach from ColorLink.

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3D IN THE FIELD

Practical, field-grade 3D is a growing need in many military and industrial applications. Mobile robotic platforms can benefit from stereo vision systems as can the drivers of "buttoned up" military vehicles. Polaris Sensor Technologies, Inc. (Huntsville, Ala.) is working to fill these needs through its own dual LCD monitor approach.

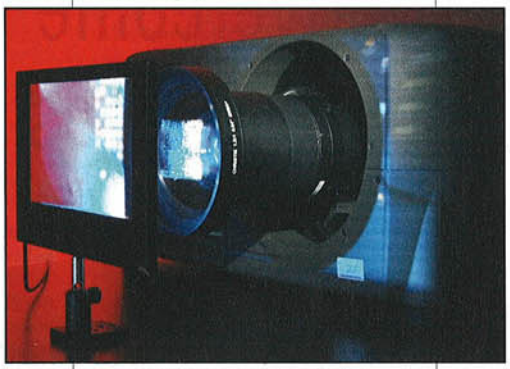
The system works by having an LCD panel receiving video inputs from two sources, such as a left eye and right eye camera, and emitting a fuzzy combined image. A second panel is directly on top of the first panel and imparts an angle of polarization to the light emitted by the first panel with each pixel getting a different polarization angle. The viewer wears a pair of polarized glasses which only allow the correct right eye image to reach the right eye and the correct left eye image to reach the left eye. This allows a slightly different full color and full resolution image to reach each eye which the brain then fuses into a single image with depth.

Rauseo noted that the system does sacrifice some light intensity, though that is compensated to a great extent by using an ultra bright backlight. In return, a full resolution 3D display system is provided that is both rugged and convenient in form factor.

"Our 3D technology is very appealing to the military because it is rugged and provides a compact size which makes it easy to fit in a dashboard or a small control console for robots," said Rauseo. "When you only have a single camera for a bomb disposal robot, you're out there with your gripper arm stabbing at a wire because you have a hard time determining how far way that wire is from your tool. If you provide a stereoscopic solution you can almost immediately just grab the wire and cut it. When you're dealing with something that can blow up on you that can be a pretty good feature to have."

Another application is in buttoned up military vehicles, where the crew has to close the hatches and drive the vehicle under fire through small vision ports. These ports not only limit the field of view, but depth perception as well.

Medical applications abound with the increase in endoscopic and other microscopic surgical techniques due to small incisions which limit tissue damage but also force surgeons to use small cameras to see what they are working on. Rauseo can also see applications in surveillance and security, where the ability to add depth can bring out details that might otherwise be missed, particularly in such environments as casinos or baggage screening machines in airports.



A single projector approach from ColorLink.

Will the dream of high quality, eyewear-free 3D be realized in a practical manner? Obviously such systems exist today—with limitations. However, it will likely be some time before they can fill the full range of specialized performance needs that can currently be met by today's cost effective polarization- or color-based glasses approaches. And with the form factor down to a pair of light, comfortable and stylish "sunglasses" the advantages of a eyewear-free approach moves more into the realm of want as opposed to necessity. AI