Photo: Baris Simsek

Visualizing the World in 3-D

From Stereoscope to the Super Bowl

By Peter B. Seel, Ph.D.

In the natural world there are two broad categories of mammals: hunters and the hunted. The former group includes species with eyes placed on the front of the head such as birds of prey, large and small cats, and human beings. Such visual stereopsis provides optimal depth perception as the slight divergence between optical pathways allows creatures such as homo sapiens to hit a rapidly moving target with an arrow or a rock. The perception of depth in self-defense, as well as hunting, has contributed to the evolution and propagation of our species. Blindness in one eye results in a loss of depth perception as the remaining functional eye provides accurate visual information, but the brain lacks the required binocular detail to create a sense of depth. I would argue that one reason that we enjoy seeing the world in three dimensions is that our sense of depth perception has fundamentally contributed to our survival and success as a species.

The creation of photography in France by Niépce in the 1820s and advanced by Daguerre in the early1830s was followed by the development of twin-lens cameras that could take stereoscopic images that mimicked the

optical convergence of the human eye. When dual images taken with these cameras were placed side by side in a stereoscopic viewer that separated the perspective of each eye, the result was a magical perception of depth. 3-D stereoscopic viewers with black-and-white images of tourist sites such as Niagara Falls and the Brooklyn Bridge were very popular in the U.S. in the late 1800s. One of the most widely-adopted 3-D viewers was invented by American novelist and poet Oliver Wendell Holmes Sr. (Figure 1).

Photo: Dave Pape (Creative Commons)

Figure 1 – A reproduction of a Holmes American Stereoscope created in 1860 by physician and writer Oliver Wendell Holmes Sr. He declined to patent the widely adopted viewer.

Readers may recall their first look into a View-Master® toy (Figure 2) and the entrancing look at cartoon characters in vivid 3-D, or seeing color images of tourist sights such as the Grand Canyon that replicated a sense of depth that a 2-D postcard could not convey. Millions of children worldwide have experienced vivid color 3-D imagery thanks to the humble View-Master toy. Humans enjoy seeing things in 3-D, either with our own eyes or via technology that converts 2-D imagery into three – and we especially enjoy 3-D images that move.

Photo: In the Creative Commons

Figure 2 – The Sawyer's View-Master® model G introduced in 1962, a century after the Holmes Stereoscope. It holds a disk with fourteen 16 mm. color slides (seen as seven pairs of 3-D images).

3-D Film and Television Technology

There are two basic types of 3-D technology used for motion media displays: active and passive. Passive systems rely on anaglyphic 3-D displays that present right eye and left eye information in the same frame and utilize inexpensive eyewear (often simple cardboard) with plastic "lenses" of red and cyan/blue or amber and blue. Passive technologies such as the ColorCode 3-D system allowed home television viewers such as the Obama family to view commercials in 3-D during the 2009 Super Bowl football game (Figure 3). The ColorCode amber lens admits color information for one eye and the blue lens admits monochrome depth information for the other – the brain links the imagery together to create the televised 3-D illusion. Anaglyphic passive 3-D technology was used with other recent telecasts including the memorial segment honoring Michael Jackson during the 2010 GRAMMY® awards.

Photo: Pete Souza (public domain).

Figure 3 – Newly elected U.S. President Barack Obama watches commercials in 3-D during the 2009 Super Bowl with wife Michelle and White House guests. The amber and blue lenses in their anaglyphic cardboard "glasses" use the passive ColorCode 3-D system.

Active 3-D systems used for theatrical projection and television displays utilize two primary methods to create the illusion for viewers of seeing 2-D imagery in three dimensions: polarized projection (or display) and active-shutter "eclipse" technology. The first method involves the use of glasses with polarized lenses that deliver alternating right-eye and left-eye visual information (Figure 4). The RealD system has been widely used for the theatrical projection of recent 3-D films such as Avatar (2009), Clash of the Titans (2010) and Despicable Me (2010). 3-D motion pictures are projected in theaters as digital images using a RealD polarizer device placed in front of the projector. The circular polarization system delivers alternating right-eye, left-eye visual information at 48 frames per second (24 left, 24 right) with each frame being repeated in a burst of three (to limit flicker) for an effective frame rate of 144 per second. Newer 3-D motion pictures require digital projection systems, which until recently has limited the number of available theater screens for their presentation. Sony estimated that 7,000 U.S. movie theaters would have digital projection systems by the end of 2010. One negative aspect of polarized systems is that the dark glasses reduce image brightness for viewers, so theater owners have increased the brightness of projection systems to compensate for this drawback.

Vizio announced in 2010 that it was developing a home television that would utilize inexpensive polarized glasses for viewing televised 3-D programming. While the polarized Vizio 3-D televisions may cost more than those sold by other 3-D manufacturers, the glasses would cost much less ($5 versus $150 per pair for active-shutter models). This technology will allow Vizio to provide numerous pairs of polarized glasses with their 3-D displays and they may prove popular with larger families and viewers who host viewing parties for major sports events.

Photo: Fritz Jörn (creative commons)

Figure 4 – Two pairs of RealD glasses are juxtaposed to demonstrate the alternate polarization of the lenses. Films digitally projected in theaters using the RealD circular polarization method display alternate digital frames for left and right eye at 144 frames per second.

Photo: Hayes 1989

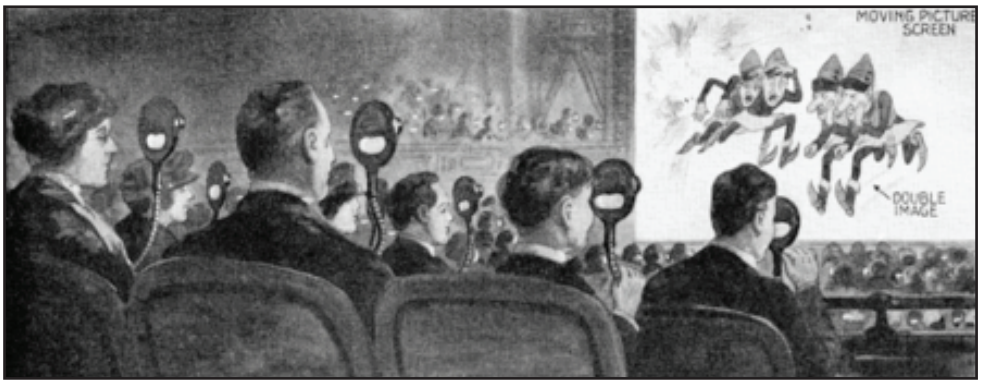


Figure 5 –Teleview patrons watch a 3-D film as seen in an artist's rendering of the system in use at the Selwyn Theater in New York City in 1922.

Active-shutter "Eclipse" 3-D Television Technology

In the summer of 2010, customers could stroll into a Sony retail store, don a special pair of electronic glasses, and watch World Cup matches in high-definition 3-D. Viewers were watching a new 3-D video technology that uses an "alternate frame" television display wirelessly synchronized with battery-powered "active-shutter" eyewear. 3-D "eclipse" display systems developed by Panasonic, Sony, LG, Toshiba, and Samsung are capable of presenting color visual information at 120 frames per second – 60 for the left eye and 60 for the right eye, wirelessly synchronized with an LCD "shutter" built into the electronic glasses. As right eye information is presented on screen, the electronic shutter on the right eye side of the glasses opens long enough for the visual information to be passed to the viewer in 1/120th of a second. The rapid refresh rate of the system creates a vivid sense of three-dimensional realism for the viewer and is similar to the 144 frames per second rate of the RealD polarizing system used in movie theaters. Taking the glasses off makes the television image looks blurry and out-of-focus as the brain can no longer decode the rapidly alternating right and left images on screen (similar again to digital 3-D projection in a theater). With the glasses on, the rapid alternation of synchronized images may alleviate the discomfort experienced by viewers of out-of-synch 3-D motion pictures in the 1950s and 60s.

The use of alternating frames to present 3-D visual information is not a new technology. Inventors Laurens Hammond and William Cassidy introduced their 3-D Teleview system at the Selwyn Theater in New York City in 1922 which utilized a viewer in front of each patron which was synchronized with alternating left-eye and right–eye film frames (Figures 5 and 6). Dual projectors were used to present right

Photo: Hayes 1989

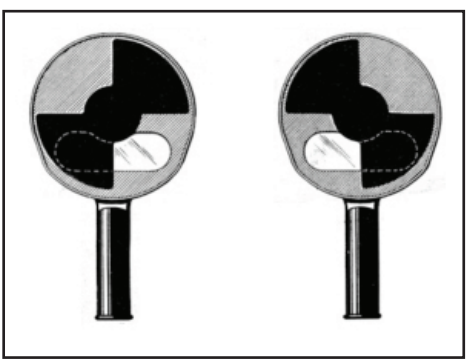


Figure 6 – The Teleview personal viewer with its synchronized shutter system.

and left eye visual information and a rotating shutter in the patron's viewer allowed only one eye at a time to see the projected film. Filmgoers who looked around the viewer would see double images on screen, but looking through it produced the illusion of 3-D moving images. To reduce the flicker on screen caused by alternating images projected at 16 fps, the inventors printed each frame three times, a system similar to that used by present-day RealD 3-D projection technology. Unfortunately for Hammond and Cassidy, the poor content of their 3-D travelogues and features could not compensate for the novelty of three-dimensional images and the show closed after 24 days. What is unique about the Teleview system and recently developed electronic "eclipse" video systems is that they each display right-eye and left-eye frames in alternate order and use a shutter in front of the viewer to control the flow of visual 3-D information.

3-D Video Production

Television manufacturers are confronted with a problem similar to the introduction of digital television: how to motivate consumers to purchase a new 3-D television set when there is limited 3-D content available for them to see? One solution that worked for the digital television transition after 2000 is being tried again by manufacturers: underwriting the production of live and recorded programming in 3-D. To this end, both Panasonic and Sony are sponsoring the creation of 3-D television content that highlights the unique visual attributes of 3-D imagery. Manufacturers are expected by broadcast executives to underwrite the additional expense of simul-casting these events in 3-D if they wish to showcase the technology to stimulate television set sales.

Panasonic is sponsoring DirecTV's creation of three satellite-delivered 3-D channels in 2010 and several networks, including CBS, NBC, Discovery, and Fox Sports, will provide programs for these channels. Sony is underwriting ESPN's telecasts of 85 live sporting events in 3-D in 2010, including the World Cup soccer matches in South Africa. ESPN has created a special channel for their 3-D telecasts that is carried by cable and satellite program providers, but the channel is dark when there is no 3-D content available. Sports programming may be an ideal genre to highlight the attributes of 3-D television. While high-angle wide shots may look similar in 2-D and 3-D, lower-angle shots of a soccer ball slamming into a goal or a football spiraling toward a receiver in the end zone are dramatic in 3-D. In April 2010, ESPN worked with CBS to televise the Masters golf tournament in 3-D, which was then cablecast by Comcast and streamed in 3-D by IBM on the Masters.com website. Viewers of sports events in 2-D will be seeing more of the odd-looking, twin-lens 3-D television cameras on the sidelines in the future as networks experiment with the technology.

A key factor that may influence consumer adoption of 3-D television is that several U.S. television networks are planning to distribute content using "frame-compatible" anaglyphic technology. This technology would allow home viewers or those watching in public places to wear inexpensive polarized glasses instead of the expensive active-shutter glasses required for high-end eclipse models. It appears that in the near term (2010-2012) most viewers of televised live 3-D content will watch with polarized glasses.

The other type of content that may drive 3-D television set sales in the near term are 3-D movies. The so-called "golden age" of 3-D movies occurred in the early 1950s with mixed results due to the fundamental limitations of the anaglyphic and polarized projection technologies of that era. Many 3-D film viewers in the 1950s complained of headaches and visual problems induced by out-of-sync right-eye and left-eye visual information and the use of poor-quality projection systems. A new golden era has developed for 3-D films since 2000, especially for animated films. It has also been a golden era for film studios and theater owners in terms of box office revenue. Film studios would like to expand that revenue stream by distributing 3-D films on Blu-ray disks for home viewing. The studios need to tread carefully as they would like to replicate the dramatic effect of 3-D films when viewed in a darkened theater, but not make it so powerful on a television set that viewers will decide to skip theatrical presentations and wait until the film is released on disk. This balancing act may be fruitless as home displays become ever larger, brighter, and sharper with the advent of new LED-LCD and plasma 3-D television technologies.

There has been a dramatic increase in blockbuster hits produced or reformatted in 3-D, with James Cameron's Avatar leading the way as the first motion picture to gross more than $2 billion worldwide. Avatar is a digital video production shot with 3-D cameras developed by Cameron and Vince Pace that consisted of two Sony HDC-F950 HDTV cameras placed in a rig that mimics the 2.5-inch intraocular distance of human eyes (See Figure 7 for a similar arrangement). The key with 3-D "film" and television production is the use of two cameras in a rig or with twin-lens cameras that mimic human binocular vision (Figures 7 and 8). The principles of 3-D image capture and display are fundamentally the same as those explored by Oliver Wendell Holmes in 1860 with his stereoscope. The addition of electronic recording technologies has enabled the creation of virtual worlds and characters that would likely render Holmes speechless if he could observe

Photo: By the author

Figure 7 – A 3ality 3-D rig (with two Sony HDTV cameras attached at left and top) is displayed at the 2010 National Association of Broadcasters trade show. This dual-axis arrangement allows the highest definition electronic cameras to be incorporated for 3-D digital filmmaking.

Photo: Panasonic

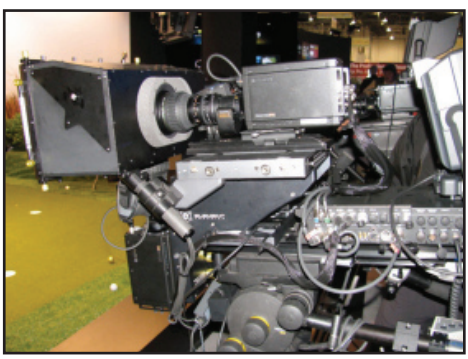
Figure 8 – Panasonic's lightweight twin-lens camera designed for 3-D electronic field production records right-eye and left-eye visual information separately onto two SD memory cards. This $21,000 camera would be more practical for television news and sports production than the system at left designed for digital filmmaking.

how 3-D imagery has evolved over the intervening 150 years.

More than one hundred film titles will be available on 3-D on Blu-ray disks by 2011 and a VHS/Beta-style format war with 3-D media appears unlikely as most movie studios have agreed to use a modified Blu-ray standard for 3-D film distribution. The sale of movies on disk or for telecast to home audiences is a significant source of revenue for film studios. Twentieth Century Fox is estimated to have received between $25 and $35 million from the FX cable network in 2010 for the first telecast rights to the film Avatar (in 2-D and 3-D versions).

The Consumer Electronics Association (CEA) conducted a consumer survey in 2009 in conjunction with USC's Entertainment and Technology Center and found that, of consumers considering a purchase of a 3-D DTV in the next three years, 33 percent said would use it to for viewing 3-D television shows, while 65 percent indicated that they wanted to watch 3-D movies. This may reflect that there is more 3-D movie content available today than television shows, but manufacturers are aware that the desire to watch 3-D movie blockbusters at home may be a key factor in driving set sales.

Photo: By the author



An Element 3-D rig shown at NAB in 2010 that has one of the two HDTV cameras mounted below the matte box. This lower-profile arrangement would be preferred for television studio or stadium use as to not block the view of the audience.

Photo: By the author

An attendee at the 2010 National Association of Broadcasters trade show watches a Panasonic 3-D marketing presentation with special active-shutter glasses that are synchronized with the display via infrared signals.

3-D Display Costs and Sales Projections

Hardware costs are a key factor for consumers considering 3-D television adoption (e.g., for the display and the required electronic glasses for active-shutter systems). Panasonic's 50-inch 3-D plasma television is presently available for $2,400 (with one pair of glasses) – double the cost of their 2-D plasma display of similar size. Sony's 60-inch LED-LCD 3-D television is $4,500 with four pairs of electronic glasses included. Samsung's 46-inch 3-D model retails for $2,600 and their 3-D Blu-ray player is $400, a premium price when conventional players cost $100-150. The special electronic glasses are $150 each – and most 3-D televisions include only a single pair with the purchase. Consumers will need to purchase additional sets of electronic glasses for family and friends. One other issue – the technologies used for

the active-shutter 3-D displays differ, so that electronic glasses purchased for use with a Sony LCD 3-D set will not work with a Panasonic plasma 3-D model.

Another key metric in assessing consumer acceptance of this new technology will be the number of 3-D-capable displays sold in 2010 and 2011. In 2009, Chris Chinnock of Insight Media predicted 28 to 40 million "3-D capable" televisions in US homes by 2012 and Alfred Poor of GigaOM Network predicted 46 million 3-D sets sold by 2013. Both were optimistic estimates given the relatively slow adoption of DTV sets in the U.S. – a government-mandated conversion. Analysts at Gartner estimate that it might take five to ten years for 3-D display technology to catch on with consumers, an estimate that is in line with adoption rates at present.

Consumer Feedback

In the summer of 2010, the Cable & Telecommunications Association for Marketing (CTAM) commissioned the Nielsen Company to conduct a study of consumer reaction to 3-D TV technology. Using Sony's 3-D Experience Lab at the CBS Vision TV City in Las Vegas, Nielsen researchers asked 425 randomly selected individuals to take a pretest survey assessing their familiarity with 3D technology, then had groups of 12-15 participants watch a 30-minute compilation of 3-D sports, documentaries, and segments of a feature film in a theater setting. This was followed by another survey that assessed their immediate reactions to the 3-D viewing experience. Nielsen also conducted 12 focus groups of three to five participants who watched 3-D programming in a living room setting to gather qualitative data on the simulated home 3-D viewing experience. The findings from the study are enlightening as this is the first large-scale research project that involved actual 3-D television viewing in both theatrical and simulated home settings. While a majority (57 percent) of the participants felt that 3-D television technology was more immersive than 2-D, 77 percent indicated that they felt it was better suited for watching sports or movies than everyday viewing, and just 29 percent indicated they would consider buying a 3-D display in the subsequent 12 months.

The key factors they said would inhibit them from being an early adopter of 3-D television technology: the cost of the displays and related hardware (68 percent), not enough television programming available in 3-D (57 percent), and having to wear special glasses for 3-D viewing (57 percent). Neilsen researchers were surprised at the level of participant dissatisfaction with the need to wear special eyewear to watch 3-D programming as 86 percent thought it would "constrain their multitasking activities" and 46 percent said that they found the special glasses "uncomfortable."

Frank Stagliano of Nielsen said that, based on the findings in this study, consumers will likely have a "wait and see" attitude toward 3-D television and that "in fact, purchase interest for a 3DTV set among those planning to buy a new TV in the next 12 months decreased after seeing a demonstration of the technology, experiencing the glasses, and learning more about the product costs." (emphasis added)

The price premium for 3-D displays, electronic glasses, and Blu-ray players will have to be reduced before consumers adopt it widely. Sony stated in September of 2010 that the company

plans to include 3-D capability in all its 40-inch or larger digital televisions in 2011 – integration of this type will likely reduce the price premium. Manufacturers will also need to continue to underwrite the 3-D production and simulcast of major sporting events and other programming that will attract audiences to the spectacular imagery of 3-D television. U.S. broadcasters have just spent millions of dollars over the past two decades converting their faculties for digital television production and transmission and are unlikely to produce much 3-D content without a subsidy by manufacturers for doing so, especially if initial audiences are relatively small.

While active-shutter technology is visually impressive in terms of delivering flicker-free, sharp, colorful 3-D imagery, there may be a significant market for alternative display systems such as that proposed by Vizio that use lower-cost polarized glasses. The burden of proof will be on Vizio to demonstrate that its 3-D televisions can display program content with the clarity of competing "eclipse" technologies.

The CTAM-Nielsen study confirms the unresolved question of whether television viewers will be comfortable wearing 3-D glasses for extended periods of time. While viewers will tolerate the glasses for the 90-120 minutes it takes to watch a feature film in a theater, they may be less likely to do so for an entire day or evening of 3-D television program viewing. Survey participants indicated that the eyewear may also inhibit their ability to multitask – a common viewer activity as past research has shown. Research is underway in labs around the world for a glasses-free solution to 3-D viewing, but at present all successful 3-D television systems require that viewers wear glasses to separate right-eye and left-eye visual information.

The push for consumer adoption of 3-D television technology is being driven by display manufacturers and 3-D content producers. The U.S. marketplace for large flat-panel HDTV displays is saturated and manufacturers see 3-D as a new television technology that can command premium prices. They are willing to assist in underwriting the significant production costs of creating 3-D programming to promote television sales. Hollywood movie studios have had great success with 3-D features in the past five years and are seeking home audiences for these films. Viewers who paid premium prices to see 3-D versions of their favorite films in theaters may be motivated to create a mini-IMAX 3-D television theater in their homes. One factor that early adopters may have to contend with is having enough pairs of special glasses for all their new friends who plan to stop by and watch the Super Bowl in 3-D.

Peter Seel is Associate Professor in the Department of Journalism and Technical Communication at Colorado State University. He is presently working on a book titled Digital Universe about digital telecommunications to be published by Wiley-Blackwell in 2011. He has written extensively on the diffusion of digital television and is co-author of the 'Digital Television and Video' chapter in the 12th edition of the Communication Technology Update and Fundamentals (2010) text. Dr. Seel's teaching areas include television production, digital photography, new media technologies, and telecommunication.