3-D Stereoscopic Cinematography

by Rob Hummel

You arrive at the theater, about to see a 3-D movie. You get a pair of polarized glasses. The movie starts, and you are amazed how objects seem to reach deep behind the screen, and at other times, objects come right off the screen, appearing to hover above the audience member's head in front of you. Is this the latest 2009 3-D release of an animated feature film?

No, I'm describing what happened as you walked into the Chrysler Pavilion at the 1939 New York World's Fair to watch *Tune in to Tomorrow*. That was the first public use of light-weight polarized glasses for a 3-D motion-picture. Even Dr. Edwin Land, the inventor of thin sheet polarizing material, was involved in the production.

Yet even this is predated by John Anderton, who was granted a US Patent on July 9th, 1895 for "Method By Which Pictures Projected Upon Screens By Magic Lantern Are Seen In Relief." Anderton had already obtained patents in England (July 7, 1891) and France (Oct. 8, 1892). His technique utilized polarized projected images and glasses; however he used polarizing crystals instead of thin sheets of plastic, so it never ended up being very practical. What we're witnessing today are improvements on technologies that are over a century old. Stereoscopic cinematography is more complex than one article can cover. This is intended as a primer on the basic constructs of a complex medium, one that I hope will encourage further research on the subject. In order to save some ink, we will cave to convention and henceforth refer to stereoscopic cinematography as "3-D."

Definitions

Left Eye: Photographed images that are intended to be seen only by a person's left eye. This term can refer to the lens or camera that is capturing the left-eye images, or the left-eye images projected in a theater.

Right Eye: Photographed images that are intended to be seen only by a person's right eye. In 3-D Cinematography, often called the Master Eye, or Dominant Eye.

Stereoscopic: Refers to the dual imagery obtained when viewed from two vantage points slightly offset horizontally from one another. Quite simply, it is what we observe when viewed with our left and right eyes, and gives a sense of dimensionality to objects closer than 13' to 16'. Also called "binocular vision."

Monocular Depth Perception: Refers to depth perception not requiring dual image cues, or the depth perception that comes into play with objects farther than 13' to 16' away.

Screen Plane: The position in a theater where the projection surface is located; a vertical plane coincident with the screen that helps define where objects appear in front of, behind, or on the screen.

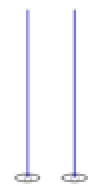


Fig. 1 When we look at something on the horizon, our eyes are focused at infinity and look straight ahead.

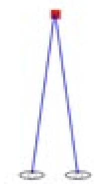


Fig 2. Eyes Converging on a close object.

Convergence: What happens with the human visual system as two images seen with the left and right eyes become overlaid so they become one image. When looking at an object at infinity, your eyes are looking straight ahead (Fig. 1).

Convergence happens when stereoscopic depth perception comes into play, i.e., when objects you are targeting/focusing on are closer than 13'-16' (Fig. 2). When focused at infinity, objects close to you appear as two transparent images; as you converge on those close objects, they become one solid image, and objects in the background become double images. Convergence in 3-D Cinematography is when the two taking lenses are aimed to converge on a single point in space.

Plane of Convergence: The vertical plane where your eyes are directed to converge on a 3-D object. If an object appears to be floating in front of the movie screen, the plane of convergence is where that object appears to be. The same would apply to objects appearing to be "behind" the screen.

Proscenium Arch: In 3-D projection parlance, this refers to the edge of the screen which becomes important when an "off screen" object approaches the edge of the screen and becomes occluded (blocked).

Interocular: the distance between your eyes. Also known to your optometrist as interpupillary distance, when you are fitted for prescription eye glasses. Most people have interocular distances of about 6.3 cm. Often confused with Interaxial...

Interaxial: Very import term in 3-D, it is the distance between the centers of the left and right camera lenses. In 3-D Cinematography, the interaxial distance between the taking lenses needs to be calculated on a shot by shot basis. Within reason, the interaxial can be altered to exaggerate or minimize the 3-D effect.

The 3-D Cinematographer must weigh several factors when determining the appropriate interaxial for a shot. They are: focal length of taking lenses, average screen size for how the movie will be projected, continuity with the next shot in the final edit, and whether it will be necessary to have a dynamic interaxial that will change during the shot. Because the interaxial distances are crafted for a specific theatrical presentation, a 3-D motion picture doesn't easily drop into a smaller home viewing environment. A movie usually will require adaptation and modification of the interaxial distances in order to recreate the same stereoscopic effects in a small home theater display screen environment.

Once you become enmeshed in the world of 3-D, you will encounter many differing opinions on the appropriate ways to photograph and project a 3-D image. For example, when you're originating images for large-format 3-D presentations (Imax, Iwerks, etc.), some people will direct you to photograph images in ways that differ from the methods used for 1.85:1 or 2.40:1 presentations. Part of this is due to the requirements for creating stereoscopic illusions on a large-screen (rather than small-screen) environment, but approaches also derive from personal preferences. In this article, we're trying to just present the indisputable facts, and avoid the emotional interpretations of stereoscopic imaging. Those unfamiliar with stereoscopic cinematography think it involves merely adding an additional camera to mimic the left-eye/right-eye way we see the world, and everything else about the image-making process remains the same. If that were the case, this article wouldn't be necessary.

First of all, "3-D" movies are not actually three-dimensional. 3-D movies hinge on visual cues to your brain that trigger depth stimuli, which in turn create an illusion resembling our 3-D depth perception. In a theatrical environment, this is achieved by simultaneously projecting images that represent, respectively, the left-eye and right-eye points of view. Through the use of glasses worn by the audience, the left eye sees only the left-eye images, and the right eye sees only the right-eye images.

Most people believe depth perception is only created by the use of our eyes. This is only partially correct. As human beings, our left-eye/right-eye stereoscopic depth perception ends somewhere between 13' and 16' (4 to 5 meters). Beyond that, where stereoscopic depth perception ends, monocular depth perception comes into play.

Monocular depth perception is an acquired knowledge you gain gradually as a child. For example, when an object gets larger, you soon learn it is getting closer, and when you lean left to right, objects closer to you move side to side more quickly than distant objects. Monocular depth perception is what allows you catch a ball, for example.

3-D movies create visual depth cues based on where left-eye/right-eye images are placed on the screen. When you want an object to appear on the same plane as the movie screen, both left- and right-eye images are projected onto the same location on the screen. When photographing such a scene, the cinematographer takes into account the apparent distance of the screen plane to the audience and then chooses the appropriate lenses as determined by the width of the field of view.

For example, a wide landscape vista might create a screen-plane distance that appears to be 40' from the audience, whereas a tight close-up might make the screen appear to be 2' from the audience. *Fig. 4* illustrates when an object is at the screen plane and where the audience's eyes converge while viewing it. (*Fig. 4* also effectively shows where your eyes converge and focus when watching a standard 2-D movie without special glasses).

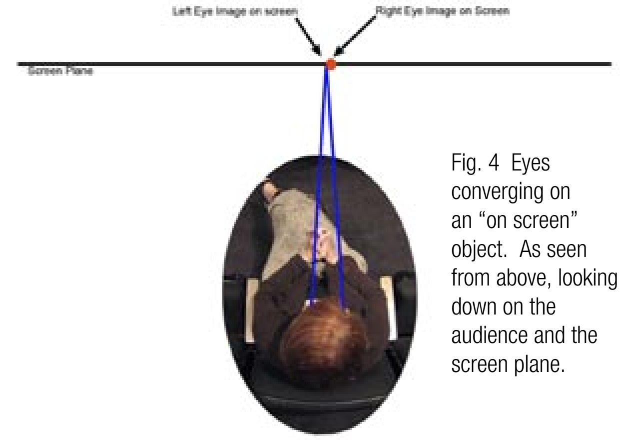


Fig. 4 Eyes converging on an "on screen" object. As seen from above, looking down on the audience and the screen plane.

If we want an object to appear behind the screen, the image is photographed with the lenses converged behind the screen plane. On set, the screen plane is an invisible plane that you establish to control where objects will be placed by the viewer of the 3-D film. In the theater, of course, the screen plane is a very real, physical object. When a behind-the-screen object is projected, it looks similar to what is shown, *below, in Fig. 5.*

In Fig. 5, the right-eye and left-eye images are kept separated by the special glasses worn by the audience; in other words, the left eye sees only the left-eye image and the right eye sees only the right-eye image.

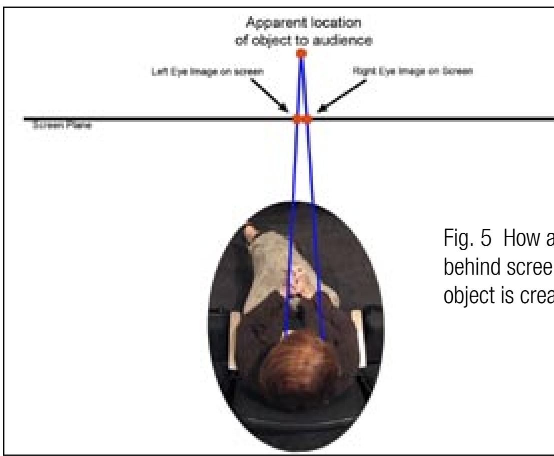


Fig. 5 How a behind screen object is created.

If you were to remove your glasses, you would see both images simultaneously, *like this, Fig. 6:*

Fig. 6 A projected 3-D image viewed without special glasses

Next, we want an object to appear in front of the screen plane, so that from the audience's perspective, the object appears to be coming into the theater and closer to the viewer's face. This is achieved on set by adjusting the angulation of the left- and right-camera lenses so they are converging in front of the theater screen plane. When projected, the images are viewed by the audience as illustrated in *Fig. 7*.

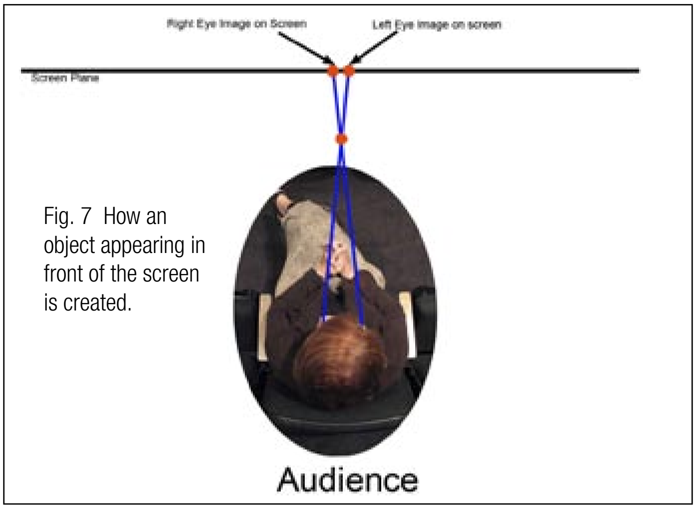


Fig. 7 How an object appearing in front of the screen is created.

This technique can be used to make audience members perceive that an object is very, very close to their faces. It creates a very effective 3-D illusion, but experience has shown that extreme examples of this effect should be used sparingly, if at all. Remember that while viewers will be converging that object mere inches from their eyes, they will still be focusing on the screen plane many feet away. As a result, this type of 3-D "gag" (when properly done) always gets gasps from an audience yet, because of that disparity of focus, never quite matches reality.

This example illustrates an important difference between 3-D movies and what you experience in real life. In life, when an object is half a meter from your face, your eyes converge and focus at half a meter from your face. In a 3-D movie environment, you can choose an angle of view and scale that, from your perspective, makes an object appear to be half a meter from your face even as your eyes are focused on the screen plane, which may be anywhere from 4 to 30 meters (15' to 100') away from you.

That doesn't mean the 3-D approach is "wrong"; it's just an example of why 3-D depth cues in a 3-D movie often seem to be exaggerated — why 3-D movies seem to have more enhanced stereoscopic depth than reality.

When an object appears on the screen plane, every member of the audience sees the object at the same location on the screen because the left- and right-eye images appear precisely laid on top of each other (and thus appear as one image). Basically, the image appears the same as it would during a regular "2-D" movie projection (*Fig. 8*).

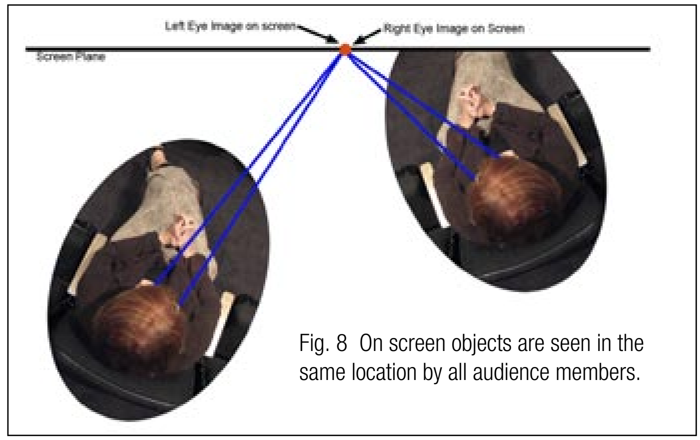


Fig. 8 On screen objects are seen in the same location by all audience members.

Take a look at *Fig. 9, below,* however, and see how things change when an object is placed behind the screen plane. Your specific location in the theater will affect your perception of where that behind-screen object is located. Also, how close you are to the screen will affect how far behind the screen an object appears to be; the closer one's seat is to the screen, the shorter the distance between the screen and the object "behind" it appears to be.

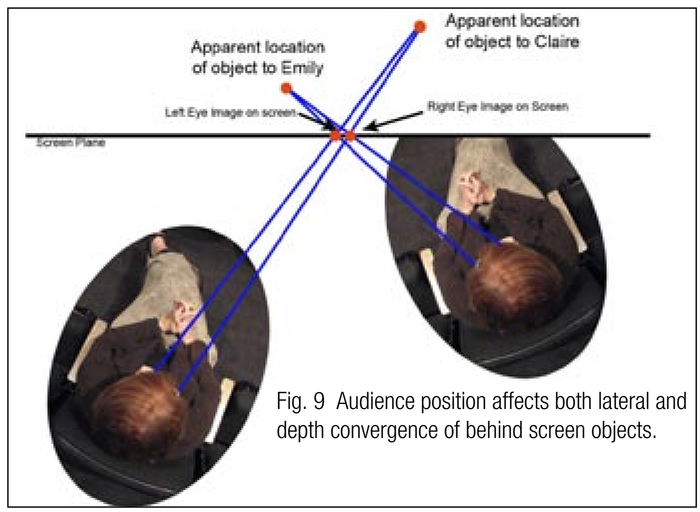


Fig. 9 Audience position affects both lateral and depth convergence of behind screen objects.

Again, it is not "wrong" that this happens. *Fig. 9* simply clarifies the point that stereoscopic cinematography is not 3-D. Were it truly 3-D, every audience member would see these behind-screen objects in the same location. When planning shots for a 3-D motion picture, the filmmaker should be conscious of how a dramatic moment might be received by viewers seated in various locations. Audience position will also affect the perceived location of off screen objects as well.

My next points concern the proscenium arch and "off-screen" objects. As mentioned earlier, the edges of the screen image (top, bottom, left and right) are collectively referred to as the proscenium arch. This is a nod towards live theater, where the term applies to that area of the stage in front of the curtain. In 3-D, the term is used when referring to objects that appear to be in front of the screen plane. In short, the edges of the screen are relevant to objects appearing in front of the screen plane. Such an object can have very strong stereoscopic convergence cues that will make it appear to be "floating" very close to a viewer's face. A good example of this phenomenon occurs in the film *Muppet*Vision 3D*, during a scene in which the characters Waldo and Kermit the Frog appear to extend into the audience while clinging to the end of a ladder. A more recent example of this principle can be seen in *Beowulf*, when a spear is thrust toward Beowulf's face after he arrives on a beach.

If that floating object moves so close to the edge of the screen that it is occluded by that edge, your brain will quickly employ its knowledge of monocular depth cues, and your perception that the object is floating in front of the screen will diminish to the point of inconsequence. Your brain has learned that when one object is occluded (blocked) by another, the occluded object must be farther away. In spite of all the stereoscopic depth cues, your brain knows that if that object is occluded by the edge of the screen, then it must be at or behind the screen plane. This scenario will be very noticeable to viewers as their brains attempt to sort out these contradictory depth cues.

Monocular depth perception overrules stereo depth cues because we are hard-wired to protect ourselves from danger. Because most danger (such as an approaching lion, bear or saber-toothed tiger) starts from outside our stereoscopic depth zone, it's easy to understand how the brain defaults to the depth cues that govern most of our life. The 3-D axiom to remember is that off-screen objects should never touch the edge of the screen, because if they do, the illusion will be disrupted. The illusion is most effective with objects that can float or be thrust toward the audience. You will also notice that when you experience these illusions, filmmakers are keeping the off-screen objects closer to the center of the screen in order to avoid the proscenium arch.

As with many axioms, however, there is sometimes an exception. There is a scenario in which an occluded object can still appear as though it is coming off the screen. Imagine a medium shot of a man who walks from behind the screen plane toward the screen plane, and then continues toward the audience until he is in front of the screen. Surprisingly, this shot will still work with the character apparently coming off the screen, even though the lower half of his body is cut off by the bottom of the projected image. The requirement for it to work, contrary to our earlier axiom, is that the viewer must have other audience members in front of him, with the bottom of the screen occluded by people's heads. When the bottom of an object is occluded by people very close to you, your brain will still believe the object is getting closer. However, even a clear view of the bottom of the screen will result in a fairly good effect of the man coming off of the screen; because we're programmed to look straight ahead, and often don't see, or focus on the lower half of a person coming towards us. Obscuration of the lower half of a person usually won't entirely ruin the off screen effect.

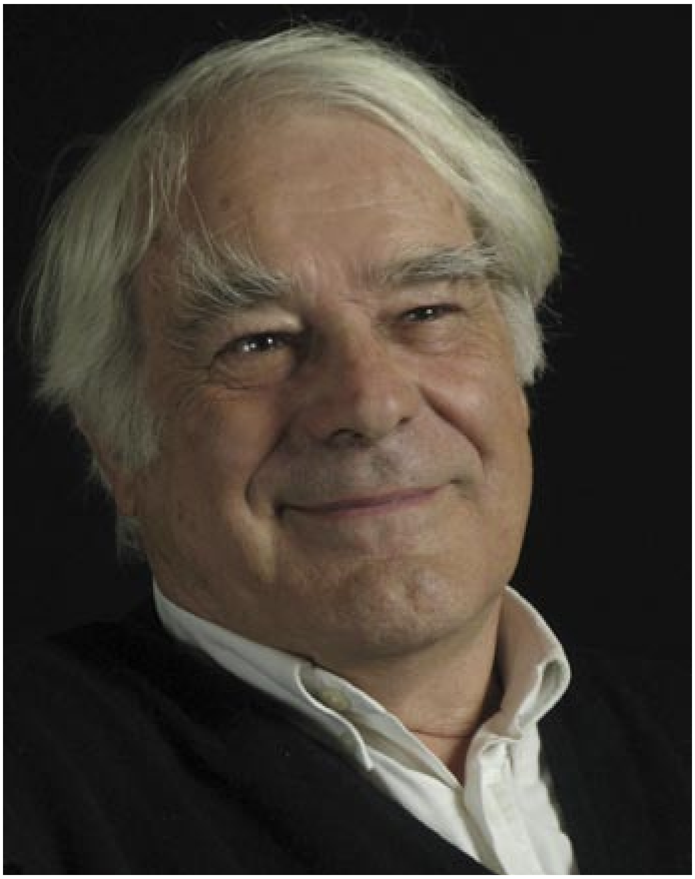
One must also be aware of the constraints on editing in 3-D. This concept is relatively simple to grasp but is often disregarded to the detriment of a 3-D presentation. When editing for 3-D, it is important to consider the convergence extremes that the audience will experience in order to realize the stereoscopic illusion. For example, if the audience is viewing action that occurs behind the screen plane, it is inadvisable to then cut directly to an object in front of the screen. The average viewer will have difficulty converging the suddenly "close" object, to the point where he or she might see double images for several moments.

Experienced viewers of 3-D films won't have this problem, and this can lead to mistakes if you happen to be part of the creative team involved in a 3-D production. If you work extensively in post for 3-D movies, you become more and more adept at quickly converging disparate objects. However, your audience won't have the advantage of exercising their eyes as much as someone working on a 3-D film. If this disparity isn't taken into account, the resultant movie can cause problems for the audience. The filmmakers will have no trouble watching it, but the average viewer will be fumbling for Advil, finding it difficult to converge 3-D images that cut between extreme positions in front of and behind the screen plane.

Some 3-D films attempt to guide the viewer to converge objects in front of the screen. They do this by slowly bringing an object closer to the audience, allowing viewers to track the object as it comes farther and farther off the screen. The makers of the theme-park attraction *Captain EO* accomplished this with a shot of a floating asteroid that comes off the screen at the beginning of the film. In *Muppet*Vision 3D*, the effect is created with the simple gag of a "3-D" logo positioned at the end of a broomstick that is pushed into the audience's face; the effect is repeated at the end of the film with the shot of Kermit perched at the end of a fire truck's ladder. In *Terminator2: 3-D*, Robert Patrick's molten head slowly comes out off the screen towards the audience. Sound complicated? It is! That's why before you embark upon your Stereoscopic 3-D production, you must do your homework, and ideally work with an experienced Stereographer.

Rob Hummel seen in 2D at the ASC clubhouse. Rob Hummel's career has revolved around understanding and explaining how the use of visual images complement the telling of a story. At places ranging from Technicolor, Disney, Warner Bros., and DALSA, Rob's understanding of the underpinnings of how to achieve the best imagery possible has helped him optimize production workflows from Animation to Digital Intermediates. You'll often find him hosting some panel or seminar helping explain arcane concepts so that all can understand.

My Impertinent Education



by Alain Derobe, AFC

I've always managed to avoid talking about myself, but today it seems I have my back against the wall. And suddenly I realize that I have never been conscious of the real motivation that had pushed me towards filmmaking, research and invention.

"Real" has always seemed to me a better word than "superficial," even if it seriously hampers a behavior which I know is sometimes not so spontaneous. Everyone searches his or her early childhood to dig out a few reconstructed memories that could be the foreshadowing signs of one's future job or destiny. No such interesting signs with me, except an exceptional laziness endowed with a lack of memory which also revealed this lazy turn of the mind. In order to counterbalance this painfully weak memory, I stubbornly tried to understand the inner workings of any phenomenon, and I desperately searched for the ultimate and final reasoning that would save me from the smallest mnemonic effort. Like a kind of Materialistic Explanation Worshiper!

I was an unwieldy child, and progressively my young days became pure hell, for the more I grew up, the less I understood life. I never guessed that all the grown-ups around me had no understanding about society, war or politics, nor the complex relations between men and women, but pretended they did most of the time.

During the Second World War, we had to move endlessly from one home to another because my parents were surrealistic radical intellectuals, and my family was torn between collaboration and resistance, between extreme-right and revolution, with a bigot branch and a violently anticlerical one. How was I to know which path to follow when I was tossed around between different educations all year long? I wanted to "understand" life, and not to accept it in all its complexity! Indeed, filled with mistrust and defiance, I came out of prostration only because of an irrepressible and indistinguishable curiosity.

Obsessional curiosity is the key to this person; I had to explain how an indolent boy turns passionate and how relentless work as a transient step from laziness would later allow a well-deserved rest. (I'm now seventy-three, and I promise to warn everybody when the time to rest has come…)

Do you remember one of Rudyard Kipling's "Just So Stories" about this Elephant's Child and his satiable curiosities, who was never satisfied with evasive answers and kept asking—as very small children do—why this and that, again and again? Civilized grown-ups are much too used to reply in vague and brief words to the questions asked, and having to go to the bottom of things makes them angry because they think it's a waste of time and energy. The adults' exasperation led the Elephant's Child to have his nose pulled by the Crocodile, and because neither wanted to let go, the nose grew longer, and that is why since that time elephants have trunks.

You must know that my taste for uncomfortable questions, and this impossibility to be satisfied as long as the ultimate relationship between cause and effect has not revealed its secrets (almost like a mental illness), is my own professional trunk, which incidentally, makes my identification easy.

Consequently, I will not linger much on my half-century long career as Director of Photography which brought me the image culture that founded the researcher I am now. Before that, after having reluctantly started biology and chemistry studies (only explosions were really interesting), I was lucky enough to be sacked from the university before having to pay for the wreckage. Then I turned towards architecture and especially town planning, thinking I could force other people to follow the social organization that I myself was totally unable to follow. I was obsessed by the sadness of cities, and turning back to my chemist's beginnings, I endlessly asked each teacher how to make colored concrete.

I was told that the architect's role was to draw freehand Doric, Ionic and Corinthian cornices you never see on buildings, but look very nice on blueprints, and that my stupid questions concerned mostly construction companies. My trunk was already growing. When I was also thrown out of the Beaux-Arts, I rejoiced in having saved ten years of my life, because learning architecture in France, in those times the most backward country in the world, took of course more time than anywhere else (7 years for architecture plus 3 years for town planning). When I was twenty, with no work and no studies, while strolling, I accidentally bumped into a shooting location where I stayed, dumbfounded, for a full day. Apart from one or two people working hard, a large number of others kept their bottoms warm on the arc light ballasts, drinking coffee, and remaining inactive mostly the whole day. Without understanding that waiting is harder than working, I was led to believe that this trade fitted my latent laziness and I immediately joined a cinema school.

I discovered very early the irritating question: "Why doesn't it look the same in the picture?" Apart from unsatisfactory answers such as "the medium cannot record all the light range," and so on, none of the faculty really answered the questions. I had an eye on all these excuses that they were using to hide their lack of knowledge about the basics, and I pointed out: "What about backlit shots? They are neither concerned by latitude nor represent original light values, but they are still the nicest shots, aren't they?" As I had brought exasperation, I was answered: "Yes, of course, but here we have an artistic phenomenon."

This sort of ageless weak argument ran down my growing trunk, and having read all that had been written about the fundamentals of photographic process (Jones, Mees, Evans, Ansel Adams, Zaccharia Kowalewski, etc.), I decided to find the answers myself by studying thoroughly the vision system.

Having become since 1967 a non-conformist Director of Photography, and having created with every feature an original and provocative solution, I started experimenting with the "transfer from reality to photography " system and published the results in 1975. As soon as simultaneous reports about the work of Dr. Edwin Land were published in "Scientific American," I understood I was not following this path alone, and that photography would stop being empirical kitchen recipes and start claiming scientific bases.

Everything I had the opportunity to teach concerning lighting, applied sensitometry and electronic transfer was based on this obsessive knowledge of vision, which is the necessary fundamental path to explaining transfers.

Applied sensitometry had taught me that the S-curved response belongs to the human vision and to nothing else, neither to physics nor to chemistry, and that technical as well as artistic explanations are found in vision itself. In 1990, when I was asked advice about 3D stéréo, which I knew nothing about, I was lucky to make my first steps with Noël Archambaud, Chris Condon, and with a few guys who had broken out of the Soviet Union, as well as with the excellent book by Lenny Lipton. I also owe a lot to François Garnier and his team who trusted me and to Claude Baiblé who shares his questioning with me, and also many others, whom I heartily thank for their faith in me.

In return, I've decided to pass on everything I could discover, share systematically any progress of knowledge and to disclose everything. And because you learn even more while explaining things, I am now certain that systems, machines, software and operating procedures are not that important, and that the knowledge of vision mechanisms is what matters. Indeed, the stereoscopic image is not the end result of a repeated automatic transfer, but the conclusion of repeated choices which involve compressing depth in a certain manner to represent it in the limited space of the theater.

A Stereographer (stereo-cinematographer) is the author of the depth he chooses to represent, even more than the photographer concerning his framing or lighting. He is an artisan, not an employee in charge of a machine or a system. Image culture will never be replaced by a device, and if I have built myself so many rigs for stereo shooting, it is because I could not get otherwise what was necessary for vision requirements.

The first significant shock happened when Noël Archambaud told me in 1990 that he was dreaming of a rig with variable spacing that did not exist at that time. He was right and since then several researchers including myself have built these rigs. Variable spacing seems, at first sight, against nature since our eye-sockets are fixed, yet it is the only solution to ensure the cinema-goer comfortable viewing.

Indeed, there will be no durable exhibition of stereo 3D features without a minimal viewing comfort of all the audience whatever the differences or the variations of their vision. That is why I've convinced P+S Technik to market rigs inspired by mine. But more than the shooting system, it is the perfect control by the Stereographer of all the 3D parameters that counts. The real technical revolution can be found in the new monitors dedicated to stereo 3D such as Transvideo's CineMonitorHD monitors that allow stereographers to master space so they can put it in the can. The depth represented on the screen will be called from now on a scenic box and will obey its own laws that I intend to state in my next book.

Meantime, in return, I am subject during my stereo 3D courses to a chain of disrupting and fundamental questions that push me to an essential competence that allows stereo 3D to blossom, whatever the system.

Alain Derobe is a Stereo 3D Consultant. Since 1992, he has worked exclusively as a stereographer and consultant for shooting in 3D. He was Director of Photography on over 20 feature films, about 300 commercials, multi screen systems (360°) for theme parks and special applications. He has shot several 3D films so far. As there was no equipment available, he decided to build his own tools to operate and promote Stereo 3D. He was stereographer on "Safari3D", "Camargue", "Chartreux", "Irruption", "Héros De Nimes", "La R'volle","Réveil Des Géants" and many others. He is a founder of the A.F.C (www.afcinema.com) and chairman of the Stereographers association UP-3D (www.up-3d.org).

Alain Derobe on the P+S Technik 3D Rig

The first rigs marketed by P+S Technik were calibrated to satisfy mainly HD users with conventional camera series such as Sony 750, 790, 900 etc. and Panasonic 3000 and up, especially with fixed focal lenses. Designed mostly for shooting with actors, the possibility to reduce interaxial distance solves many close-up and depth problems between the actors, without tiring the audience's eyes.

The module's size complies with this situation. Stereo 3D tolerates very well dolly or crane shots, in the studio or in natural sets, where weight and size do not seem to be a major problem. Since the mirror cannot have an unlimited width, 12cm (4.7") interaxial distance with a short focal length (7mm ⅔" Zeiss, more than 69°) appears to be enough before changing to a side-by-side rig for very long range shots.

On the contrary, this module is oversized for cameras with detachable heads such as Silicon Imaging for which a less cumbersome rig will soon be offered. Heavier cameras like F23 or F35, and those built by traditional film camera manufacturers will request strengthening the current module's base plate.

This rig is built in Germany, meaning it is near perfection. It offers two significant and original features. Calibrated positions allow the cameras to move back for lens change and to return to their position rapidly, and the mirror can be tilted to instantly correct vertical superimposition defects.

Angle and interaxial counters are very attractive but their readings become secondary when using Transvideo's CineMonitorHD 3D View.

I am somewhat doubtful about the more theoretical than practical possibility to raise and lower the mirror to readjust perfectly relative lens heights. This complex mechanism adds weight to the rig and in the first version reflections of metal parts can sometimes appear, but for which modifications can be asked.

You could think this type of adjustment is unnecessary, since there can be consequences only in very hard to achieve tight close-ups when so close to the mirror. This could be optional.

Except for exterior shots in bad weather, I prefer removing the front glass, even if it has an anti-reflection coating. This procedure should be simplified in the future.

The flare caused by the mirror is visible only if direct lighting shines onto it. There is no other solution than to protect it, because a direct reflection seen by only one camera is unacceptable. Backlight with the sun in or close to the frame is indeed a serious problem.

A slight difference in black level between two cameras – the real flare – is part of the difference observed between two cameras and is within vision tolerance. Anyway, I can't think of finishing touches without a final stereo adjustment nor without grading added to the shot-by-shot fine tuning. Shoots performed until today have generated very few problems of that type but it is true that the Stereographer's role is to hold back the request for risky shots.

Example of a 3D Shot

Here's a very instructive lesson I've done with Jerzy Kular during stereo 3D courses for filmmakers that I would like to repeat every time.

We shoot a wide shot of an industrial zone with buildings in the far background, taken with a normal focal length lens.

The camera is over 2m (6ft) High, to lessen the influence of the ground.

A car moves forward at high speed towards us, while the camera booms down to meet it. The car stops with its huge headlight a foot away from the 3D rig, the enormous protruding eye covering almost half the frame.

On the other half of the frame you can see the driver stepping out of the car and walking away from the camera towards the buildings.

This shot is extremely significant and answers many questions.

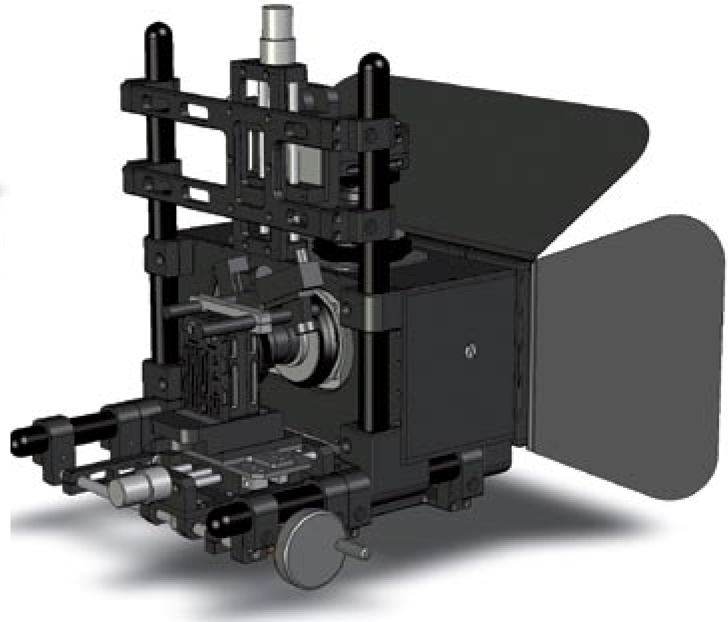
In the beginning, for the wide shot, the spacing was 10cm (3.9") to offer a visible depth. This spacing was then progressively reduced to reach 1.5cm (3/8") for the close-up when the car stops at the end of the shot.

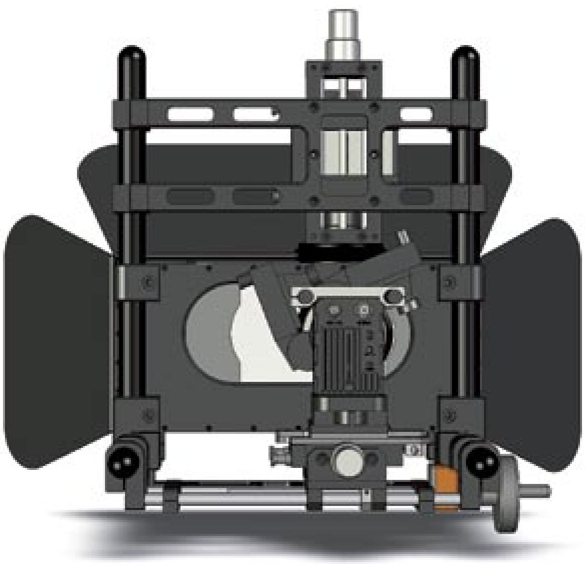
The angle between cameras has stayed the same.

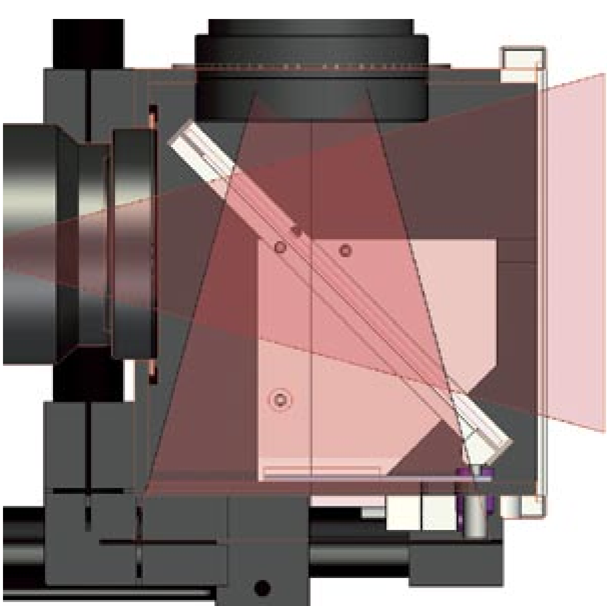
During screening, nobody sees any discrepancy whatsoever. The different depth spacings stay in place and neither are compressed nor expanded. The car does not look like a miniature in frame when the shot starts and the character is not a giant at the end. The headlight that is large on the screen is perceived, of course, as enormous, but not more than with a wide-angle lens during a flat shooting—and it answers a desired effect.

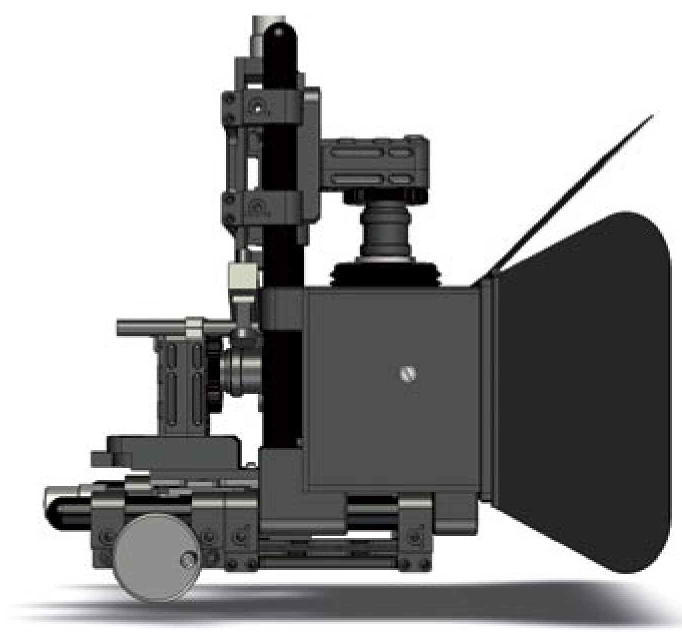
This shot could be included in a police film sequence and teaches us that down-sizing, gigantism, and respecting the ocular distance are relative to the environment, and one should not hesitate to use variable spacing when needed. In this case a rig with a semi-reflective mirror is absolutely needed.

P+S Technik 3D Rig









My Steps to Stereography

by Florian Maier – Stereographer and Engineer

I'm a consultant on new developments in movie making and work as a stereographer on 3D productions. I also take great pleasure in presenting 3D workshops, where I can teach people about 3D. I like to explain the essential differences between good and bad 3D production. I think this is important, and the only way to ensure a secure future for 3D as a new way of storytelling. Otherwise it will disappear again, as it has in the past.

I have always been very curious about life, nature, exceptional images and technical things. 3D is one of the most interesting things because it combines physiology, perception psychology, technical science, the joy of filmmaking and the production of visual art in order to create an exceptional look.

When I was a teenager I shot small films with friends and built my own little studio in my basement. I started to work in TV and film studios (e.g. Bavaria Film Studio in Munich). At 18, I started my own production company for advertising and image films – I was still in school at this time. I decided to build my own 3D rigs, and since that time, 3D wouldn't let go of me. A little bit later I developed a multi camera technique called "Frozen Reality", where I combined the old idea of Eadweard Muybridge's multi camera array with high speed photography and picture interpolation (www.frozen-reality.de).

In 1999 I attended the HFF film school in Munich. A year later I began studying interdisciplinary media technology at the Technical University in Ilmenau. I continued researching and working on many 3D projects, developing apparatus for autostereoscopic recording (3D without glasses) and 3D film recording – and worked on films at the same time. After I finished my engineering degree I started to work full time as a 3D consultant on different projects.

In 2006, I met Alfred Piffl, head of P+S Technik. Some months later he asked me to consult and help develop Alain Derobe's unique 3D Mirror Rig into a universal production model with additional features.

We wanted to create a 3D Mirror Rig that was unique and different from all previous rigs, universal for most camera types, very accurate, able to match both cameras and very easy to calibrate. I don't think there is anything else like it on the market today. Most rigs are only available for rent or only come with the entire 3D crew. Anyone can buy the P+S Technik rig.

The first feature we designed for the P+S Technik 3D Mirror Rig is its universal usage with many different cameras. Different adapter plates match the correct height, since almost every camera has different measurements and heights. Different mirror box sizes are available to fit the different needs of the user to choose between maximum compactness or wider angle lenses.

The second new feature is the ability to calibrate the geometry of both cameras simply by adjusting the 300 gram mirror instead of a 10 kg camera. Tilting the mirror is the equivalent of tilting one camera (in order to bring the optical axes parallel). Moving the mirror forwards or backwards is the equivalent of a change in height of one camera (necessary to avoid vertical parallax).

The third feature is having two accurate, repeatable counters for interaxial (distance between the two cameras) and angulation (convergence setting) that can be fed by the data of my STEREOTEC Stereoscopic Calculator (in order to calculate the right interaxial and convergence settings). Two additional counters match the distance from the mirror.

The fourth new feature is a quick-release mechanism so that you can back the whole camera very easily away from the mirror box in order to access the lens. You can change your lenses without losing the calibration end stop. Once you change the lens, you can simply slide the whole camera into the remembered, calibrated position. Changing lenses can be done quickly.

All these features make the 3D Mirror Rig from P+S Technik a practical tool on set or on location.

3D Calculator

Florian Maier's STEREOTEC Stereoscopic Calculator helps you find the exact settings for a 3D Rig. It calculates the interaxial (distance between the two cameras) and the angulation (convergence, if you decide to shoot converged) by asking you to enter parameters like distances on the set, the kind of lens you use, screen size, etc.

With the Stereoscopic Calculator you can create the look you like, depending on the preference of the stereographer.

First of all, you can calculate the maximum possible interaxial, without exceeding the viewer's limits (from a physiological point of view). That doesn't mean you have to use this maximum. The stereographer can, for example, decide to use just 70% of the maximum depth possible, or he can decide by referring to the resulting screen parallax that is shown in the screen tab of the Stereoscopic Calculator.

The professional version will have settings to shoot orthostereo or autostereo among other advanced features. It will be released soon on Windows, Mac and Linux; later it will be available for handheld devices. The Stereoscopic Calculator is a handy tool for the set, and ensures good 3D without headaches.

You can find a demo and more information about the Stereoscopic Calculator and other tools for 3D recording as well (e.g. 3D rigs for special applications) at www.stereotec.com

Features of the Standard Version

- calculate the maximum allowed interaxial and adapt it to your needs.
- calculate the right angulation (convergence) if you shoot converged and not parallel.
- all important HD cameras and lenses with exact data included.
- take into account the size of the projection screen.
- take into account the focal length.
- display the interaxial at the screen.
- limit calculation to certain maximum screen parallaxes (separate input of positive and negative parallax).
- Save and load complete settings.

3D Workshops

Florian Maier (*below*), 3D expert and stereographer, presented 3 day 3D workshops to sold-out sessions in NY, LA and Vancouver organized by ZGC, distributors of P+S Technik products including the 3DStereoRig. *(Les Zellan, above, right, rear.)*

For anyone contemplating a 3D production—producing, shooting, editing, distributing, this is an essential education. There's a lot to know and a lot of things that can go wrong if you don't know. But Florian demystifies a process that has long been closely guarded by gurus, and makes it accessible for all.

The workshop teaches you how to prep, rig, shoot, edit, present, and more. Florian compares good and bad 3D, reveals the secrets of the pros, explains the difference between gentle 3D and Advil 3D, and above all, shows that 3D is a viable, practical format with a healthy future when done right.

Equipment included the 3D Rig from P+S Technik, two Sony EX3 Cameras on an OConnor 120EX Fluid Head and Legs, Transvideo CineMonitorHD 3DView, and more. There will be more seminars in the future. For more pictures from the seminar, go to: picasaweb.google.com/fdtimes
Florian can be reached at www.3d-consult.eu

ABCs of 3D

By Florian Maier (3D Consult)

The new buzzword is 3D. Everybody is talking about 3D. But shooting good 3D involves a unique vocabulary and a specialized toolset. Over the years we've seen 3D come and go. The first wave began in the middle of the 19th century with the introduction of Charles Wheatstone's Stereoscope. The 3D boom in films began in the 50s and was like a series of waves every ten years. In between we always had 3D as a niche-market format. But now that 3D is returning, what ensures that it will stay this time and doesn't disappear again?

One main reason could be that it is going digital: from shooting to exhibiting. The advantages over analog techniques are easier and cheaper production. Digital display technology is getting better and better—not only projected in the theater, but also monitored on set. A 3D shot can be viewed live on set or location, instead of days later. This can help avoid mistakes.

Good and appropriate 3D story content is another factor that should keep it going this time around. Many times in the past people tried to get audiences into cinemas by adding 3D as an effect to an otherwise 2D movie. As a result, people often associated 3D with "cheap tricks" eye popping effects, where something smashes into your face. But this style of "exaggerated" 3D is dangerous for a 90 minute 3D movie, because every time something pops into your face, you're thinking about the 3D effect and not about the story any more.

In my opinion, a good 3D movie is one where you forget, after twenty minutes, that you're sitting in a 3D theater, and are instead more involved in the action of that movie. It's like being there, and not just watching it.

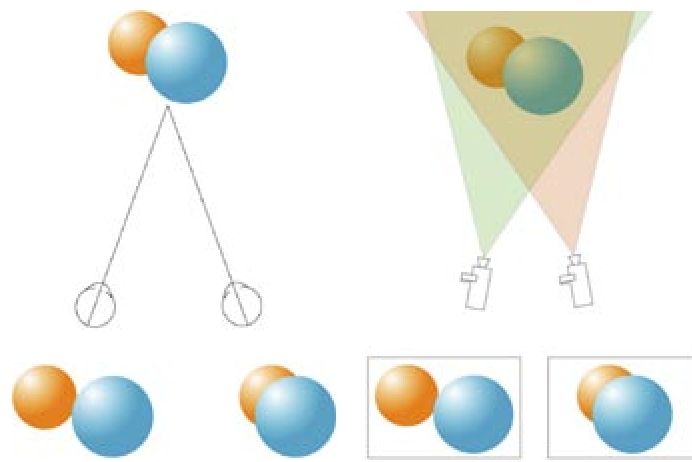
Another very important thing, in my opinion, is that you should use the right 3D setting very carefully when shooting a 3D movie, in order to avoid eye-strain and headache. I call it "gentle 3D". To be gentle, you have to choose the interaxial very carefully. (Interaxial is the distance between the two cameras.) Calculating the correct interaxial distance is not that simple, because it changes depending on parameters determined by the camera, lens, distances in the set and the screen size where it will ultimately be projected.

For that reason, I developed the Stereoscopic Calculator. It doesn't replace a Stereographer or a person who knows about the art of three dimensional movie making. Many details have to be considered.

The most important thing is that the story has to be appropriate to 3D and vice versa. A 3D movie cannot be shot like you would shoot a 2D movie. A lot of physiological rules have to be respected. But if these rules are respected a 3D movie can become a pleasant experience and that is exactly what is needed to keep 3D successful as a new way of storytelling, just as sound or color became established elements of movie making art.

Basic Principle of Stereoscopic Vision

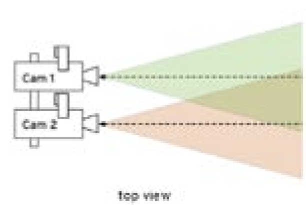
To be able to see spatially, human beings have binocular vision. Each eye sees the environment with a slight difference in perspective; which we call parallax. The brain uses these two slightly different views to generate a spatial impression.



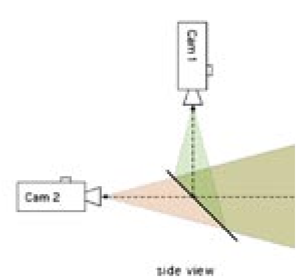
To deliver the two views with that slight difference in perspective, a scene must be recorded with two cameras instead of the eyes. These cameras are synchronized to record the scene from two different perspectives; the distance between these positions is called **interaxial**. To be able to see a movie in 3D, the left eye needs to get the view of the left camera and the right eye the view of the right camera. The brain is then able to combine these two images into a single three dimensional image.

Two kinds of 3D rigs

There are two different kinds of 3D rigs. With a 3D side-by-side-rig, both cameras are placed next to each other. With a 3D Mirror Rig, a beamsplitter physically overlaps and overlays the field of view of both cameras. A Side-by-Side rig is often used for shots of objects that are far away, like a landscape or aerials. It also can be used when your cameras and lenses are physically very small and narrow. A 3D Mirror Rig makes it possible to create very small interaxials (distance between the two optical axes of the cameras) even with large cameras in order not to exceed the limits of human vision for very close shots.



Side-by-Side Rig



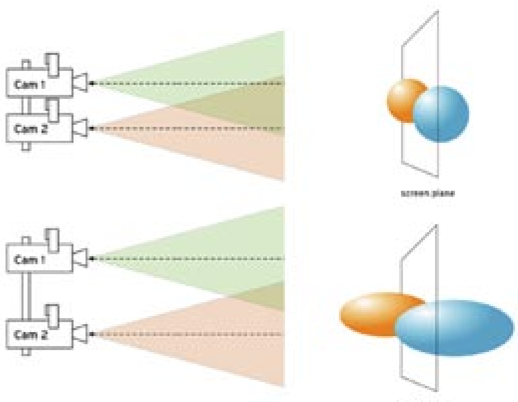
Mirror Rig

Side-by-Side Rig

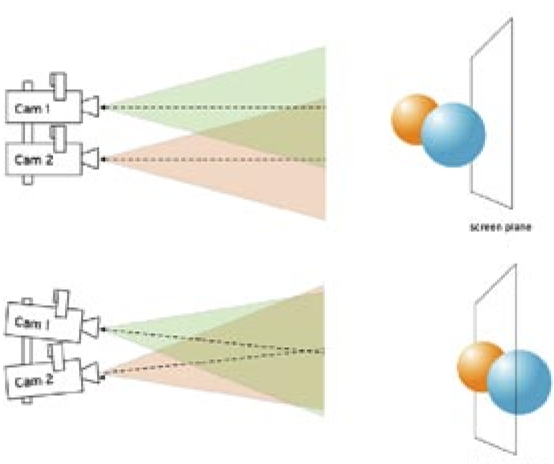
Mirror Rig

2 important principles of shooting with a 3D rig

By adjusting the interaxial (distance between the optical axes of the cameras) the overall 3D depth from the nearest to the farthest point can be changed.



By adjusting the angulation (convergence) between the two cameras, the position of the 3D object relative to the screen can be changed. That's how you make objects "jump off" or recede farther away from the screen.



Glossary of 3D Terms

accommodation: focusing on an observed point.

angulation: angle between the optical axes of two cameras.

autostereoscopy: seeing a picture three dimensionally without additional aid (glasses), as in holographic screens.

binocular: with both eyes.

convergence: pivot point of both optical axes to an observed object.

depth cues: information about the depth of a scene; there are monocular depth cues like perspective and binocular depth cues like stereopsis.

deviation: displacement of corresponding points between left and right image

far point: the farthest point from the entrance pupil of the lens.

interaxial: distance between the optical centers of the two lenses.

interocular: distance between people's eyes. About 6.3 cm.

motion parallax: change of angular position of two stationary points relative to each other as seen by an observer, caused by the motion of an observer.

near point: the nearest point from the entrance pupil of the lens.

entrance pupil: point about which a lens is rotated where close and distant subjects focused on the film plane maintain their relative positions to one another. Often incorrectly called nodal point.

parallax: change of angular position of two stationary points relative to each other as seen by an observer. If there is no parallax between two objects then they occupy the same position.

pseudoscopy: inversion of the spatial impression. Background appears in front of foreground. Rotate your polarized glasses 90° to try it.

screen plane: image plane mapped directly on the surface of the screen.

screen parallax: distance between two corresponding points on the screen surface.

stereopsis: ability to make fine depth discriminations from parallax provided by the two eye's different positions on the head.

Transvideo 3DView and TITANUM

Monitors include Waveform, Vectorscope, Histogram and Overexposure Control.

Marianne Exbrayat with CineMonitorHD6 3DView at Band Pro Expo.

Transvideo makes HD Monitors not only for film-style standard video assist, but also for 3D production. All three Transvideo CineMonitorHD monitors have 3DView, which provides the essential technical and pre-viewing tools needed on 3D HD productions. CineMonitorHD 3DView can be used as a regular HD SDI monitor. It includes several pairs of Anaglyph glasses. Optional Shutter Glasses plug into the monitor via a small box; they give a realistic color preview of the 3D picture. The CineMonitorHD 3DView is in use on several 3D sets worldwide and is an indispensable tool because it saves time and helps you eschew tables and computation for many stereoscopic setups.

- Colored monochrome modes facilitate correlating 2 HD SDI cameras by showing the fringes on each side of objects.
- 3 pseudo Anaglyph modes allow preview of 3D pictures from 2 HD SDI inputs.
- Vertical and/or horizontal reverse for the inputs keeps both images upright with beam splitter 3D Rigs.
- Vertical grid generator helps to adjust the separation of the cameras on the far layers.
- Measurement tools simultaneously show the 2 signals for black level, white level and flicker adjustment.
- The 2 HD SDI signals must be genlocked.
- The 3D functions are available in 720p, 1080i and PsF, but not yet 1080p.

Transvideo CineMonitorHD 3DView all have:
- Color, Green Screen, and Monochrome display modes.
- 4 :3 , 16:9, and Anamorphic.
- Safe Area Markers.
- Horizontal, vertical flips & autoflip.
- Zoom & Move functions. User set-ups.
- Frameline Generator & Matting Generator.
- Up to 3 programmable color frames.
- Advanced Measurement tool.
- Toolset for video measurement, including RGBY Waveform, Vectorscope, Histogram, and Overexposure control.
- 2 SDI input & 1 SDI reclocked output on BNC.
- Galvanic insulation of the power supply.

CineMonitorHD 3DView Specs

CineMonitorHD6 3DView
6" Hi-Definition monitor for 3D and 2D D-Cinema
High brightness display 1000 NITS with LED backlight
Viewing angle optimized for body-rig use
Left Right Down 80°, Up 60°. Power 10 to 36V DC on XLR4 (-1,+4) 15.5W
Weight 1200 grams, 2.6 lbs - including bottom Slide with ¼-20 nut.

CineMonitorHD12 3DView
12" Hi-Definition monitor for 3D and 2D D-Cinema
High brightness display 1000 NITS
Left Right 85°, Up 70°, Down 80°. Power 10 to 36V DC on XLR4 (-1,+4) 30W
Weight 3700 grams, 8.1 lbs

CineMonitorHD15 3DView
15" Hi-Definition monitor for 3D and 2D D-Cinema
High brightness display 1200 NITS
Left Right 75°, Up 50°, Down 60°. Power 11 to 36V DC on XLR4 (-1,+4) 50W
Weight 4850 grams, 10.6 lbs

TITANUM: Wireless HD SDI & SD

Stop the presses! This just in: the TITANUM is a new wireless system developed by TRANSVIDEO. It uses MiMo OFDM digital technology, featuring HD SDI and SD wireless transmission. The TITANUM carries an HD 4:4:4 10 bit video signal.

The TITANUM will be available in different configurations, with or without analog audio channels.

The picture at left is a prototype; we'll see the real ones at NAB.

Preston Wireless 3D

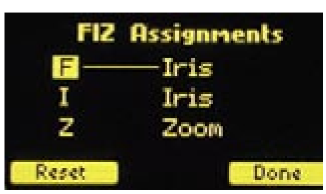
Preston MDR
Motor Driver Receiver Unit

Focus and iris settings of both lenses in a 3D rig can be simultaneously controlled with one hand-unit. Also, your Stereographer is probably wirelessly controlling the convergence and interaxial distances of the 3D rig with a second hand-unit.

Here are some tips on using a Preston wireless hand unit to control focus on both lenses, and how to use another wireless hand unit to control the 3D Rig. For complete and detailed instructions, get the FI+Z/HU3 Manual in the downloads section at: www.prestoncinema.com

On the Preston Hand Unit 3, go to Custom mode. Here, you can assign the three MDR (Motor Driver) lens motor channels (focus, iris, and zoom) to user designated Hand Unit controls. For example, the focus knob of a single hand unit can control the focus rings of up to three separate lenses.

The focus function of a 3D camera rig using prime lenses can be controlled using the Custom mode. The Custom mode is configured by pressing Set-Up. The letters F, I, Z in the left column represent the three outputs for lens motor cables on the MDR (Focus, Iris, Zoom) and the column on the right shows the hand unit controls.



This example shows that the Iris slider of the Hand Unit will simultaneously control both the Focus and Iris outputs on the Motor Drive Unit. So, to control the irises of both lenses in your 3D rig, plug one iris motor into the Focus receptacle and the other iris motor into the Iris receptacle of the MDR. Note that the zoom motor is still controlled by the zoom control.

The 3D mode is used in conjunction with 3D rigs that have motorized control of both the camera convergence angle and interaxial camera separation. After the user sets the convergence distance, the interaxial distance can be changed "on the fly" and the convergence angle will automatically change to maintain the correct convergence distance.

cmotion 3D software

cmotion
camin
Motor Driver
Receiver Unit

There's new software from cmotion for their wireless lens and camera control systems: C3D. The new 3D software comes with all new units, and is available to update all existing models. One camera assistant can use a single coperate hand unit to control the focus, iris and zoom of two lenses together with Start/Stop function for both cameras simultaneously.

Here's how to control multiple lenses with one control unit (knob/slider/zoom):
1. Make sure the coperate is turned off.

2. Press and hold the "LENS" button on either the focus knob, slider or zoom – depending on which component you want to use for control.

3. While pressing the lens button, press the ON button.

4. Hold both buttons for at least 3 seconds. This process will activate the 3D software within the camin. The coperate's RDY LED will now turn green. The LENS LED for each controller not in use will turn red.

Note: If the CAL-LED starts blinking, lens calibration is required. Push the CAL-Button. This will calibrate all connected motors. You can also switch between the control unit (knob or slider) during 3D mode.

With one camin, 2 motors (e.g. Focus) can be run simultaneously, and with two camins up to 6 motors can be run. The second camin is connected to the first using a CBUS 3D cable. All communication signals received by the first camin are then replicated by the second camin, including Start/Stop control. Should the need arise; cmotion 3D software also makes it possible to connect an additional camin for control of 3+ cameras and 9+ motors. Detailed instructions available in the download section of www.cmotion.eu

Editing in the 3rd Dimension

by Michael Phillips – Solutions Manager, AVID Post Market Segment

Stereoscopic editing, or Stereo 3D for short, is an old but new-again challenge for filmmakers.

Digital technologies have solved many of the issues associated with the format in the 50s and 60s. Things like film weave and anaglyph glasses have given way to high-resolution, rock-steady images viewed with higher-quality technology that does not affect the color values of the image. Such technology improvements have renewed the interest in stereo 3D storytelling—not only for theatrical, but for television broadcast as well.

Media Composer v3.5

Avid's first offering in stereo 3D editing is with Media Composer v3.5. This release implements a hybrid environment that brings together the existing 2D editing world with 3D viewing.

Editing can be done in 2D within the main editing interface while the client monitor will play back in stereo 3D when viewed with glasses. It would be quite fatiguing for the editor to sit in front of a system for 8-10 hours a day editing with glasses on—where the eyes are struggling to focus on stereo 3D content inside a 2D graphical user interface.

In addition to solving the comfort factor of the editors themselves, it also removes costs. Having to conform left and right eyes for screening adds unnecessary time and expense to the process when all you really need to do is check a sequence for pace and rhythm. By creating a hybrid workflow within the editor, Media Composer solves both issues.

How Does it Work?

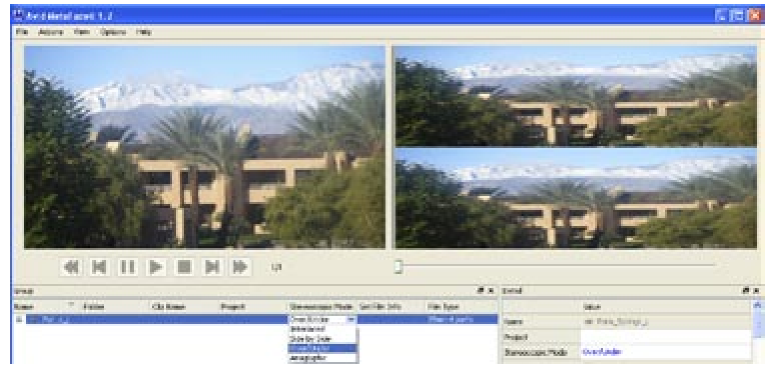
The first version of Avid's stereo 3D editing supports what is referred to as an over/under format. This is a single master clip and media file that encompasses both the left eye view and the right eye view together. The left is the upper half and the right eye is the lower half.

So for a 1920 x 1080 frame size, each eye is a 1920 x 540 proxy. It's the full picture, but it appears "stretched" and sort of looks like an anamorphic image on the edit monitor *(graphic 1, above)* until you select either right or left eye.

Because Media Composer handles metadata better than any other system, tracking left and right eye sources can be done very easily. This is done with separate metadata columns.

For video-based productions, the timecode will be the same, but depending on shooting format there may be two tape sources. In file-based workflows, the filenames themselves will be different and can be tracked as such. All of this metadata can be exported as EDLs via Avid EDL Manager and XML via Avid FilmScribe. The XML XSD files can be found at www.avid.com/filmscribe.

For file-based formats, the left and right eye sources can be prepared for editorial using Avid MetaFuze. This free application available from www.avid.com/metafuze will take directories of left and right eye files and create over/under files in the Avid DNxHD format of choice as the stereo 3D proxy of choice. *(graphic 2, right)*

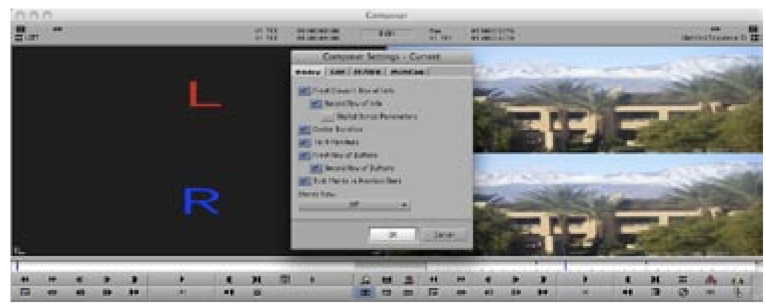


graphic 2

Once the media is in Avid Media Composer, editors then choose which eye they want to be the dominant eye during editorial for the 2D view. This is done via the "Composer" settings. The choices are:

- OFF (over/under)
- LEFT (top half only as full 1920 x 1080)
- RIGHT (bottom half as full 1920 x 1080)

Graphic 3 is an example of OFF (None) and shows the media as it comes into the system while Graphic 4 *(below)* shows the result of selecting LEFT.



graphic 3

The next setting affects the full screen playback which is the signal that goes to the client monitor. This is done via the DVI output of the graphics card. The user can select "checkerboard" which creates the stereo 3D signal used by consumer type monitors by manufactures such as Mitsubishi and Samsung. *(Graphic 5)*

graphic 4

These monitors are rear projection DLP that use the "3D Ready" tag as the indication that they support the checkerboard format. Active shutter glasses can then be used with the monitor for stereo 3D viewing. When the production team is ready to view an edit in 3D, it is a simple matter of putting on the glasses and watching the playback in 3D. The Checkerboard setting can be turned off and either a LEFT or RIGHT eye view can be selected to output a full screen 2D version. This setting gives the flexibility to output as needed for the desired viewing environment and monitoring available.

graphic 5

The Future

Avid is working closely with stereo 3D content creators to enhance the stereo 3D post production process. Additional formats such as interlace and side-by-side as well as some basic depth grading tools via AVX are being investigated. This will allow for even greater control in the storytelling process, resulting in even greater efficiencies to ensure the continued success of stereo 3D storytelling.