Stereo3D

Entertainment for the 21st Century

What you are seeing could the next big thing in TV – Stereoscopic 3D.

Hollywood is already embracing Stereo3D film. Now, around the world, Broadcasters and Games manufacturers are developing Stereo3D.

Stereo3D content is created by shooting or rendering (or ‘dimensionalising’) two eye views with a horizontal parallax offset.

Stereo3D Televisions are able to extract each eye and show them on the TV screen. The viewer gets a stereoscopic image by wearing passive or active glasses.

The TV screens on the market today work with conventional 2D SD and HD content too.

Now, read on to find out more about what services could we expect, how could we get them and when might they happen.

If you want to discuss Stereo3DTV just send me an email at:

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Stereo3D – some lessons from history

Stereo3D film is already here and it is highly likely that Stereo3D TV will follow. However, some people are sceptical, just as some people were sceptical about colour and sound. Both colour and sound had false starts and it was a series of breakthrough movies which gained commercial and critical acceptance for the two technologies against sustained resistance:

Breakthrough movies finally convinced studios about sound and colour

'Talking pictures will never replace the silent drama'
Joseph Shenck, United Artists, C.1928

'I consider the so-called "all-talkie"….nothing but rotten trash'
Sergei Eisenstein, 1929

'The reaction to talking pictures is somewhat problematical. Talking throughout the entire picture has a tendency to retard the action'
Pat Powers, Cinephone, 1929

"The process of Color motion picture photography [has] never been perfected…it would tire and distract the eye, take attention from faces and acting and facial expression, blur and confuse the action…."
Douglas Fairbanks, 1930

And then a few years later:

'Whether color can make black and white pictures as obsolete as sound made silent pictures, is, as suggested, quite another question. The silent picture was slain overnight by the jawbone of Al Jolson, whose Jazz Singer threw a hitherto sceptical industry bodily into speaking likenesses. But color is not so pronounced a revolution as sound'
Fortune Magazine, 1934

By early 1929 all the important studios in Hollywood had become thoroughly sound conscious. This was a great help to us in introducing color. Prior to that studio executives were loth to permit any change whatsoever in their established method of photography and production. But with the adoption of sound, many radical changes became necessary. Technicolor was always confronted with objections photographing in color required more light, different costumes, a knowledge of color composition, additional time, and one or the other of these points, plus the added forceful argument that it cost more money, made it difficult for us to get started.

In my opinion, the turning point came when we ourselves produced the series of short subjects. By entering the field as a producer, by keeping very careful records of our time and money schedules, and by openly discussing with studio executives everything that we were doing as we went along, we dissipated most of the prevailing misinformation.
Technicolor Founder H. Kalmus, 1938

A personal favourite book is Alvin Toffler's influential 1970's 'Future Shock' which predicted a near-future where the speed of change is faster than we can absorb. He predicted this would disorient people and generates many negative reactions. Here we are in that future and he was right. Film and TV are technology driven businesses, yet as in many other industries, many people dislike change.

A very recent case is Digital Intermediate – the process of digital colour correction of movies. Digital Intermediate took about two and a half more years than actually needed to gain full acceptance, mainly because of some highly emotional resistance, although the benefits were quite literally there for anyone to see. Now, almost every movie goes through the DI process.

Of course, many much-hyped film innovations prove nothing but fads and there's nothing wrong with some healthy scepticism. Emotional resistance is unhelpful, constructive rational scepticism is healthy. As individuals and as an industry, we have a responsibility to rationally think about new technology. The world isn't going to wait around for us.

Objections fade if and when it's clear a new technology delivers real benefits – either to the content maker or the audience. The most compelling argument is of course money. If a new technology can either save money or make more money that tends to get attention. Show business is a business.

Digital Stereo3D film making is already being enthusiastically embraced by Hollywood because of current evidence that the numbers work.

Assuming you have a film that already appeals to an audience, Stereo presentations get more cash through the door. Last year, Hannah Montana smashed box office records and this year dozens of titles are in production.

There are some who think Stereo3D is just a passing fad. Some say that Stereo3D already failed once in the 1950's and that what counts is making good content. However, similar arguments were used against sound and colour in film. When film makers of the 30's made good films that used sound and colour that audiences would have gone to see anyway then sound and colour thrived. What sound and colour did was enhance the audience experience.

Now good movies - that happen to use Stereo3D - are getting good box office. As long as we make good films there is no reason for Stereo3D films to be a short lived fad. In the analogue 1950's we simply did not have the technology to make consistently good stereo films in a reasonable time and at a reasonable cost and there were many issues with projection. Now with digital capture, digital post and digital projection, the situation is wholly different.

It follows that the key argument in favour of Stereo3D Broadcasting is the overwhelmingly positive reaction the general public has to it. As an industry we do well to always consider the general public. They are everyone's customers. We aren't here just to sell to each other.

What exactly do we mean by Stereo3D broadcasting?

One definition of Stereo 3D broadcasting might be:

‘The transmission of a high quality left eye and right eye signal to the viewer of a Stereoscopic ready domestic Television with horizontal parallax information extracted by viewer glasses that helps convey depth’.

This intentionally narrow definition excludes:

- Anaglyph or its variants (which is a single signal with colour used to convey depth. Although simple to do, colour quality makes this an unattractive option)
- Narrowcasting to D-Cinema theatres (although this is an interesting new area)
- Multi-view stereo that does not need glasses. This is a bit complex to broadcast today, is lacking in resolution and currently has limited ‘sweet spots’. So, right now this is not ready for prime time, especially as some proposed camera systems are being studied that use five rather than two sensors. However, things are changing fast and we should keep an open mind on systems that do not require glasses as some very smart people are working on this now and this may become very significant in the future.

Let’s break the production process down into sections – shooting, galleries and trucks, post production suites and transmission.

Shooting

A pair of matched cameras, typically spaced at roughly adult eye distance, is used to capture the image. The horizontal offset produces a binocular disparity. That binocular disparity, together with other information in a scene, including the relative size of objects, occlusion, sharpness, shadows and relative motion is used by the mind to create depth perception.

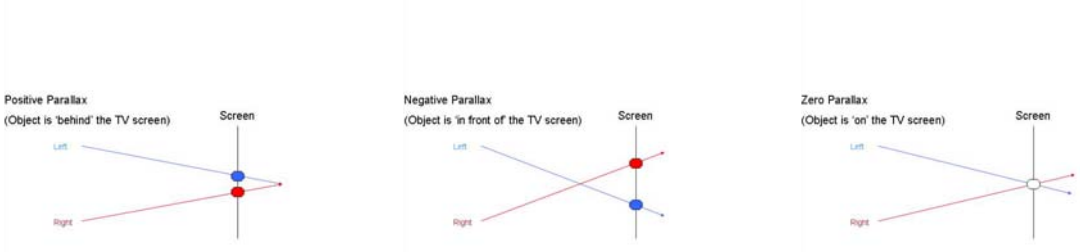
No special cameras are needed, however since the only difference between the eyes should be horizontal disparity (and not for example color, geometry or focus differences) care is needed to match and geometrically align the cameras.

Special rigs are used which range from inexpensive and simple (which can produce good stereo but only if carefully set up and very skilfully used) to highly sophisticated rigs, like the 3ality Digital systems shown here, with advanced mechanics and electronics which need minimal set up times and are easy to use.

3ality Digital rigs have been in action recently in many Broadcast tests including NFL and Sky

Shooting for Stereo3D is a different aesthetic than conventional TV. The audience is far more involved in the image and fast cuts, busy graphics, wobbly camera work or whip pans are usually avoided, in favour of a more immersive and smoothly paced style that draws the audience in. Because of this more relaxed style, less camera positions may be needed. Technically it is possible to derive a 2D image from the 3D camera positions although artistically the feel of a Stereo3D shoot is different from some common 2D styles. [1]

One important topic to understand is 'where to place the action'. Up to now much stereo has been shot for large screens, not for domestic television sets. One artistic judgement is whether to place the objects of interest in a shot on, behind or in front of the TV screen by 'converging' – which means 'toeing' the cameras inwards or outwards in a similar way to how we move our eyes when we look at objects close up or further away.



Positive, Negative and Zero Parallax

Placing objects behind the screen (positive parallax) gives a 'window' effect i.e. the viewer is looking through a frame to a scene behind[2]. Placing objects in front of the screen (negative parallax) gives the appearance of action happening in the viewer's room.

This 'in your face' style is great for certain kinds of action but care is needed not to push objects so far that the viewer can't 'fuse' them and they get an uncomfortable double image.

[1] Possibly good news to anyone who finds sports coverage to be over produced and would rather concentrate on the action.

[2] During post production, it is now possible to vary the amount of parallax without rendering, which is critical in making Stereo3D Broadcasting a practical proposition.

Also care is needed framing shots where the action comes out of screen if the objects are cut off by the screen edges. This gives a so called ‘conflict of cues’ – the image is in front of the screen yet is also occluded by the screen frame so must therefore be behind the screen.

This is much more of an issue in Television than for example in IMAX where the edges of the screen are much further out from the point of view of the audience. Converging on an object (i.e. there is no horizontal difference between the left and right images) places an object on the screen (zero parallax).

So, there are new considerations, as there was when color was introduced, but unlike the changeover to colour, the cameras are the same, you just need more.

Production galleries and trucks

In some recent tests, existing production switchers (vision mixers if you are from the UK) and existing DVEs were used. Production switchers can tie crosspoints allowing two cameras to be cut as if they were one and DVEs can be used to horizontally slide images, simulating convergence control. Graphics inserts can be made with a twin fill and key, introducing a horizontal offset between the key signals. Stereo3D live character generators are coming onto the market now.

Each camera pair can be connected to a stereo3D analyser/corrector such as the SIP2100. Convergence control can be handled either on the cameras by a convergence operator, or by a single stereographer located in the truck or gallery who controls all the cameras.

We don’t quite have all the production manufacturers committed to Stereo3D yet but this is changing fast and expect plenty of news during 2009.

One point to mention in passing is that some stereo tests use a mux/demux workflow which combines left and right eye into a single stream, allowing it to be passed down a single cable (or transmitted as a single datastream). While this reduces the resolution of the image, one curious property of stereo is that the image still appears sharp. The way we perceive stereo is still not fully agreed upon but we do know that the brain creates stereo rather than passively capturing it and, if supplied with two lower resolution signals, many viewers ‘see’ a high quality result.

There are a number of tests in progress, some using different methods to these but the common conclusion so far is positive – it can be done.

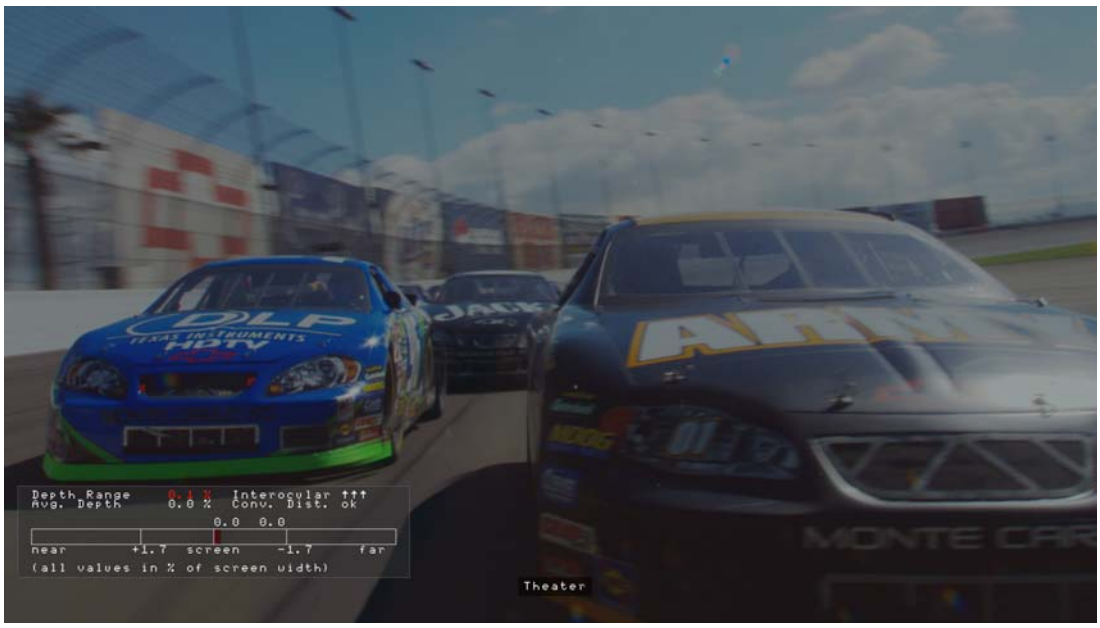
Post production suites

The ‘fourth dimension’ of stereo is time. As well as removing any stereo or non stereo image errors a critical role for post production is to create stereo that is comfortable to watch over extended periods of time. That means handling the z-space information on a shot so that it is technically and artistically correct and also handling z-space over a sequence of shots, so that the eyes can comfortably adjust.

Shooting fast moving stereo content is quite different from shooting stills (and can be different from feature film work where there may be more opportunity to set up takes). However, with a little experience any competent artist can learn how to post produce stereoscopically and as mentioned earlier there are new measurement and correcting tools coming on the market to make life easier.

Audio post is an interesting area as 5.1 can be used very effectively to enhance depth.

Today, given the right tools, post production of Stereo 3D content is becoming simpler, quicker and cheaper than ever before.



Stereo images can now be accurately measured and corrected for example using the new 3ality Digital SIP2100.

Transmission Schemes

Transmitting two full quality Stereo3D HD signals looks impractical as it uses up significant bandwidth and risks the two signals picking up unwanted artefacts. There are several schemes that aim to remove this including Side By Side, Checker Board and Stereo3D specific compression.

In **'Side by Side'**, a single signal is created that 'squashes' the left and right eye into a single picture. This is then expanded out by the viewing device.

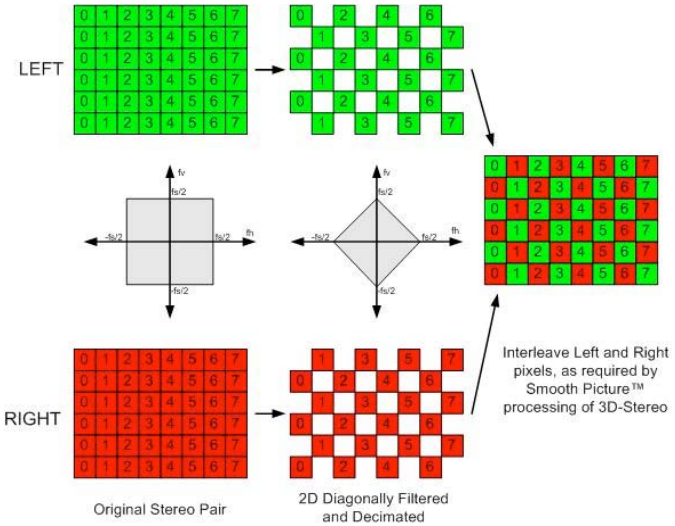
'Side by side' horizontal squeezing of the original images to one picture. Pictures are then unsqueezed in final playout.

Because we make stereo in our brains by some very complex and not fully understood methods, despite the reduction in resolution, pictures still look very good. If done properly, the actual quality is higher than many of the excessively compressed HD services being broadcast today.

A single cable can carry the signal around a Broadcast facility prior to transmission and because the signal travels as a single stream, there is no possibility of two signals getting out of sync. There is no need

for extra transmission bandwith compared to a conventional signal; however the raw signal itself produces a side by side image on a conventional TV, so in that sense is not fully back compatible in its native form. Sensio and Hyundai currently use this method.

In **'Checkerboard'**, each eye is placed in a single frame rather like a chessboard with white spaces as one eye and black as the other.

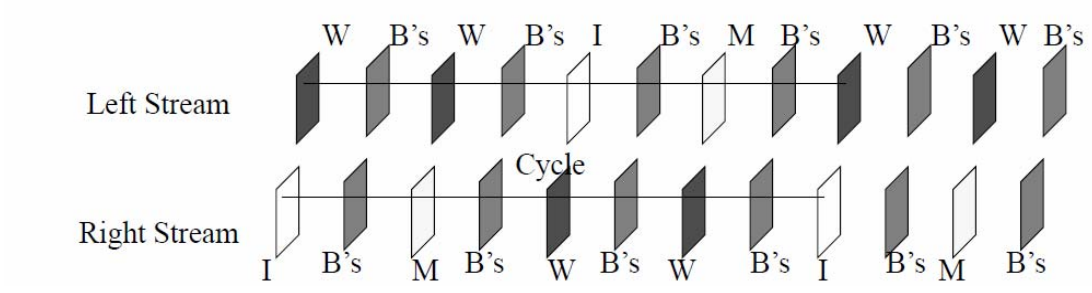


Texas Instruments Checker boarding scheme

Again there is no possibility of two signals getting out of sync and no extra bandwidth is needed.
A number of vendors already use this kind of approach.

'Stereo3D compression' includes a variety of possible schemes that take advantage of the similarity between the eyes to intelligently send only needed data.

Monocular picture streams have much redundant image content between a group of frames which can be reduced through use of long GOP compression. Stereo3D can take advantage of this too but also remove redundant data between left and right views.



Compression can be used to reduce payload by removing redundancy between eyes over time. This example is 'Worldline'

Using two channels of non Stereo3D compression is very risky to use for Stereo3D because of the possibility of concatenation or compression artefacts introducing differences between the eyes.

However good Stereo3D compression schemes are likely to find favour and companies like TDV already have working systems on the market. One potential disadvantage is that in order to maintain sufficient quality more bandwith than normal is needed – maybe somewhere approaching 1.5x – however offsetting this is the potential advantage of some schemes in producing back compatible content – i.e. monoscopic TVs will see a 'normal' picture.

Will Stereo3D Broadcast really work?

Yes. However, like sound and colour, not everyone is a believer. Here are some current objections:

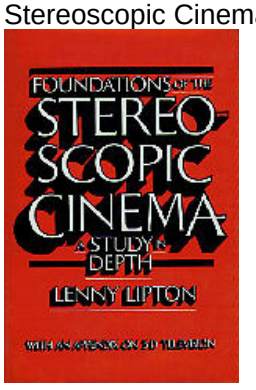
The EBU's head of emerging media David Wood said at IBC: "There is a degree of scepticism that we have enough technology breakthroughs to make 3DTV work at the moment……. the technology is seriously flawed in two main areas. The furthest point on the screen needs to be fixed at 6.5cm - the same as the distance between human eyes. This can be achieved by projection in a cinema but there's no way of knowing what size a viewer's display will be. Secondly there is a conflict between the focus and the convergence of our eyes when viewing 3D. These psycho-physical limitations can never be solved with a stereoscopic system. The real long-term future of 3DTV - and we are talking 50 years - is Object Wave recording, a subset of which is the hologram"
TVB Europe, October 2008

The first point being raised here is that stereoscopic images are created in the mind by presenting two images of a scene with a horizontal parallax difference that provides binocular disparity. That disparity makes the viewer perceive depth. The amount of horizontal parallax is important for camera operators (or CGI artists). Too little or too much and the viewer will not get the view that the Director intended (and in the worst case too much can lead to headaches and fatigue). It is correct that we need to understand and manage that depth relationship.

Just as we need to manage the amount of colour or sound in a picture (and we don't know how loud or what colour settings viewers are using at home) we need to manage the amount of horizontal parallax. There are two aspects to this – training and technology. If people know that a project will be shown on TV it is possible to take that into account during shooting and post to set up an average that will work on any screen. There is now also technology on the market to help people get it right, or if necessary automatically correct the image (just as in colour or sound we have metering but also legalisers). The technology can be used during shooting, post production or delivery.

The second point being raised is that we normally focus and converge on the same point when we look around but when we look at a Stereo3D TV screen, we focus on the screen plane but converge at a different point (the implication being that this is unnatural and uncomfortable). However, beyond a certain distance from a screen the subjective effect is negligible.

Stereoscopic expert Lenny Lipton deals with the topic of accommodation and convergence on his blog http://lennylipton.wordpress.com/2008/06/11/reality-check/. Lenny wrote 'Foundations of the Stereoscopic Cinema' one of the definitive reference texts on Stereo3D.



However, here is a different kind of objection.

James McQuivey, analyst at Forrester Research, said: "It's a very restricted viewing experience. You need to sit in a certain part of the room, and wear glasses. You can't turn your head and chat to your friend and more importantly, even if there were 100 3D films - and there are not - is that really enough to justify $1000 extra on a television. That is a big premium to pay for just a film every week or so."

The Telegraph January 2009

While it's true that there will be areas in peoples living rooms which give a better view that others, those areas will typically correspond to where they sit anyway. It's true that you need to wear glasses but as we'll discuss later there is no evidence yet about consumer acceptance.

The lack of content argument didn't stop sound and colour.

It is true that we don't have much content yet. However, one immediately available source of content will come from Hollywood as the number of new Stereo3D titles grows every month. In our tests, good Stereo3D film content made for the big screen usually works well on Stereo3D TVs with just a little adjustment. This is a 'sunk cost' as the movies are being made anyway, so with normal rights payments and some remastering there is an existing pool of film content. There are also many Stereo3D titles from the last century[3] – we've been looking at how restoration can work and it seems it makes sense for some of the better ones to be remastered. This would take a bit of time and money but is perfectly feasible.[4]

If a Broadcaster wants to put a film channel on air, there could be enough new or remastered content for a film channel to start in 2010 and each year after that the available content will rise.

Of course, as anyone following the tests and real content creation taking place at the moment can tell you, there's going to be much more than film – during 2007/2008, music concerts, game shows, wildlife documentaries, tennis, ice hockey, soccer, air races, winter sports, basketball, martial arts and American football were all shot in Stereo3D.

Finally the cost of TV sets argument doesn't hold up in the long term. Stereoscopic TV sets will come down in price to a small percentage above a monoscopic set. If the demand and the will are there, any short term issues will go away.

"While some manufacturers, such as Mitsubishi, Phillips, Samsung, and Sharp, have already begun selling 3D-ready TVs, the top four manufacturers plan to have new, advanced 3D TVs on sale toward the end of 2009 and into 2010.

But the big question is whether consumers, particularly American consumers, will be willing to upgrade to a new TV just because it has 3D. Pricing for today's 3D ready TVs is comparable to other flat-screen HDTVs. Samsung and Mitsubishi currently sell their 3D-ready TVs for between $1,000 and $2,800, depending on functionality. These prices are in line with average prices for HDTVs that don't offer 3D readiness.

Keisuke Suetsugi, a manager for the audio visual centre at Panasonic, believes that even the newer, more advanced 3D TVs will not cost much more than TVs without 3D. So for consumers already in the market for a TV, adding 3D readiness might not add much cost"
CNET Report on the 2009 CES[5]

Hollywood is very interested in Stereo3D Bluray right now and that (along with Stereo3D games) will help drive TV purchases irrespective of Broadcasting.

[3] Here are a few of the remastered titles available. http://www.sensio.tv/en/home_theater/3d_dvd/available/default.3d

[4] Also, so far 'dimensionalisation' - the process of converting 2D to 3D – has only really been discussed to Film applications. Done well the results can be excellent. In time, the economics may work to convert high value legacy Broadcast content too.

[5] http://ces.cnet.com/8301-19167_1-10142957-100.html?tag=newsEditorsPicksArea.0 However, note that the article goes on to state that "And it would likely take at least two full high-definition channels to broadcast live just one game in 3D" which is not the case.

How are Broadcasters thinking about Stereo3D now?

As a new choice. Childhood is called 'the formative years' for a reason. We grew up, like many, watching just a few channels of analogue TV. TV was something you watched passively and there wasn't much choice. There was plenty of bad TV but some was excellent. Some of the advertising was really good too.

Cutting edge 1970's TV!

But the world moved on and we need to move on too.

For kids growing up now, things are vastly different:

- Channel proliferation means massive audience dilution for the advertiser.
- Time shifting NVOD and VOD set top boxes allow viewers to fast-forward through commercials or just miss them altogether.
- Phones are delivering content.
- PC and Mac based home entertainment provided by games and Internet social networking sites are yet more alternatives to sitting down at home to watch conventional TV.
- Games consoles appeal to the young and the not-so-young. This is really important point especially as the games console manufacturers are starting to look seriously at Stereo3D themselves. That both creates new levels of competition for conventional broadcasters but also presents an opportunity for Stereo3D Broadcasters as there will be an existing population of Stereo3D TV sets which have been bought for gaming.[6] That games audience will already be accustomed to and interested in Stereo3D content.

Kids are growing up with lots of screens delivering entertainment and information. Conventional broadcast TV has no inalienable right to be the delivery system of choice in the future.

All that said, after a hard day at work, or at school, it's still great as many people still do, to sit down and relax in front of a TV – especially if you established that habit in your formative years. News and sports have also been shown to hold a good share of the audience, if done well.

All this is well known – the question is 'what do Broadcasters want to do about it?' One answer is to simply concentrate on reducing costs and maximising efficiency. That is a perfectly valid argument for some broadcasters to take. However the efficiency argument alone can't bring in new revenue or win new audiences.

There are many new potential sources of revenue - that have nothing to do with Stereo3D - that Broadcasters can adopt to offset the decline in the old 30 second commercial. These are all perfectly valid choices, however amongst hundreds of channels' Stereo3D will be a strong differentiator. Stereo3D will be one of many choices – but a spectacularly different choice.

In fact some Broadcasters considering offering Stereo TV are *counting on* limited competition, at least in the early days.

[6] http://ces.cnet.com/8301-19167_1-10134983-100.html

What's the business case for Stereo 3D broadcasting?

Digital Stereo3D Broadcasting is now being seriously studied because it is a potentially lucrative business. The technology to begin stereo broadcasting exists now and the first pilot channel is already transmitting in Japan. Show the general public and you get a positive reaction.

A key debate will be around start up costs. There were initial objections to Colour TV on the grounds of start up cost and colour took many years to roll out. Interestingly the technology costs today of moving from Monoscopic Broadcast to Stereoscopic Broadcast are much lower than the inflation adjusted costs in the 50's, 60's and 70's of moving from black and white broadcast to colour.

Compare at a headline level what technology a Broadcaster needs to change:

	Monochrome to Colour	Monoscopic to Stereoscopic	Comments
Cameras	New cameras	Same cameras	Existing HD cameras used in matched pairs are suitable for stereo
Storage	New VTRS	Same storage	Existing NAS or SANs can be used. Pairs of VTRs can be used. Some new VTRS can record Stereo signals (e.g. Sony).
Production galleries	New production switchers	Existing production switchers. Existing DVEs	Most current production switchers and twin channel DVEs can be repurposed for Stereo
Post production	New equipment	Some new, some current	
Transmission	New	Current	

So, while there are costs (and not all of them are covered here), on a technology level they are nowhere near what some people may imagine.

Can we get people to wear glasses to watch TV?

Yes. This is the objection that is the most difficult to refute technically because it is based on the tricky field of human behaviour. The evidence so far is 'yes – most but not all people will be prepared to wear glasses'. About three quarters of the world's adult population have some level of eyesight issue that glasses or contact lenses would improve. In those countries currently most interested in Stereo3D broadcasting, the majority of the adult population own glasses. Of course there is a potential vanity issue, however no one much minds wearing sunglasses outdoors if it's too bright and the need to wear earphones didn't seem to slow down sales of the Sony Walkman in the eighties.

Why then do we hear assertions like 'you'll never get people to wear glasses to watch TV'. Polarised stereo3D glasses are close cousins of Polarised sunglasses[7]. No one much seems to violently object to sunglasses – it's a multi-billion dollar business - and if you already wear glasses, it will be possible to have prescription versions made of them for Stereo3D TV viewing.

This objection can stem from a number of different factors:

- Negative experience of badly made or badly displayed Stereo 3D films.
- Negative experience of viewing content while wearing anaglyph glasses.
- Poor stereo acuity.
- An honest commitment to auto stereoscopic (glasses free systems).

Anyone who has watched poor stereo (including all Anaglyph) is likely to be sceptical that audiences can be persuaded to watch it over extended periods of time. We wouldn't want to either.

A percentage of the population have impaired stereo acuity (figures of 6% to 8% are sometimes quoted). They may see some stereo effect but often wonder what the fuss is all about. It may be worthwhile having you eyes re-checked if you are planning to work in stereo, as a change in prescription can help someone with an astigmatism.

The good news is that watching stereo at home will look much more like the first picture than the second :-)

Glasses free Stereo3D is a great long term objective but for today glasses will be the way forward.

Earphones and headphones used to be seen as 'geeky' too. Sony and later Apple made them fashionable. Maybe we need someone to pick up the challenge of producing fashionable glasses.

iPod is doing OK with earphones isn't it?

[7] There are also TV systems using active glasses and these, along with colour frequency based glasses are all possible ways of showing high quality TV pictures.

Conclusion

We know how to shoot, produce, post produce and Broadcast Stereo3D today. The content will be there in the next few years if there is a will to create it. TV sets are already on the market, more will be coming. Stereo3D games and DVD will be available.

Who knows what percentage of the population will accept wearing glasses? We don't and neither does anyone making definitive sounding pronouncements. Maybe they saw bad content. What we're reasonably certain of, based on personal experiences of working with many thousands of people here at Quantel, with partners, or on the road at events, is that if you show good Stereo3D correctly and use good glasses, many a sceptic is quickly won over. Seeing is believing.

There are lots of smart and dedicated folks in all kinds of companies working hard on making Stereo3D Broadcasting happen right now. If we want Stereo3D Broadcasting, we can have it.

Since the general public looks like they will want it too, the questions now are increasingly 'how' and 'when' not 'if'.

This isn't the whole story and there is much more to be said. Please drop me a line if you want to talk through any of these topics in detail.

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Since this white paper was originally created, last year many people have contacted me with questions, comments or request for specific information.

To keep the paper to a reasonable length I've now added three appendices:

- A short FAQ
- A section on Stereo3D Cinema
- A Stereo3D terminology appendix at the end of the paper

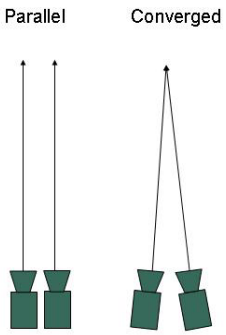
I hope these answer some of the more common questions being raised at the moment.

Appendix 1: FAQ:

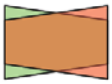
Q: What is the best way to shoot Stereo3D - “parallel” or “converged”?

A: Stereo3D Broadcasting ideology wars are already starting. This is really a question best handled by Stereographers and results are what count not theory, however at the risk of ‘stirring up a nest of hornets’, let’s look at some of the shooting concepts that have a direct bearing on how Stereo3D is handled in Broadcast production and post.

This is what we mean by shooting ‘parallel’ or ‘converged’.



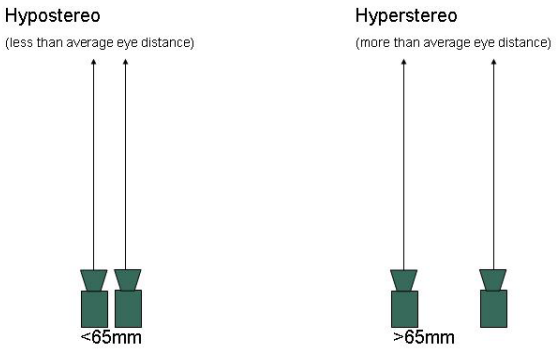
Some stereographers prefer to shoot converged i.e. with the cameras toed in so that they can choose where an object is. This is a very popular form of shooting in current stereo3D TV tests as it reduces the need for adjustment either in a truck (for live events) or in Post (for recorded events). However, shooting converged can sometimes lead to a keystoning effect:



Keystoning can however be modified during production or post production by devices with corner pinning or skew (most DVEs can do this).

Other Stereographers shoot parallel, placing all objects in front of the screen plane, leaving the placing of convergence to someone else, either in the truck or in post. Parallel in one sense is ‘safer’ because the images are not already set, however converging in post requires repositioning a whole programmes worth of shots. That’s fine on a drama or something not on a very short deadline but very problematic for close – to air content. It means work for someone[8]. Shooting parallel with the cameras set at normal eye distance can be tricky for close ups.

When shooting parallel or converged you can also choose to increase or decrease the distance between the centres of the camera lenses. This is normally set somewhere around or slightly below the average distance between the centres of the eyes of an adult (approx 65 mm).



[8] Also repositioning means a loss of information either through clipping off edges or having to zoom in to remove cut-off edges. The process of zooming removes some resolution and also may involve a tighter framing of the shot than was intended.

Closing cameras together (hypostereo) reduces the distance stereo effects can be seen and gives the viewpoint of a smaller observer (a nice trick for showing how a child sees the world). Moving the cameras apart (hyperstereo) increases the distance stereo effects can be seen and gives a 'giants' eye' view. It is also a nice trick for wildlife and scientific documentaries to give stereo3D effects on distant scenes.

While convergence can be adjusted in a production switcher (using DVEs) or in post, the distance between the cameras cannot.

Who is right? In our own experience, one argument that sometimes gets overlooked is the 'fourth dimension' which is time.

Some parts of the converged vs. parallel debate goes back to the 19th century and came out of shooting stills and other parts came out to the 1950's film boom where stereo post production was slow, expensive and not always accurate.

Now we have tools to prevent, detect or fix excessive background parallax during a shoot, which is a common criticism parallel advocates make against converged shooting.

TV content is not stills, so the role of the Director and the technical staff is to ensure the z position looks right and that any changes over time don't fatigue the audience.

Whether Broadcasters choose to let individual camera operators set up converged shots and then have the production or post production staff choose the ones to cut to, or to shoot parallel and modify the shots in the gallery, or the edit suite, will be an important topic because it will make a significant difference to the quality of the audiences experience.

Q: If you already wear glasses, do these new style glasses really work?

A: Yes. Modern passive and active glasses work on top of your existing glasses. Many people working in Stereo3D wear glasses (including me) and it really isn't a problem.

Q: Why does Stereo3D give some people headaches?

A: Good Stereo3D will not give you a headache. This fallacy is heard over and over again. Here's a very recent example:

http://news.bbc.co.uk/1/hi/business/7948947.stm

The problem only occurs when material has been poorly shot or poorly post produced or poorly displayed. This was an issue in the 50's when analogue technology struggled to produce good content at a reasonable cost in a reasonable time. Today the right technology is available. What is now needed is training and awareness to make sure the right artistic decisions are made.

Another fallacy on this BBC clip is that glasses-free lenticular displays only give you one good viewing position – in fact some displays give you many.

Q: What are the main issues in Stereo 3D Post?

A: There are still some issues in Post but these are in the process of being solved.
Customers have all the day to day issues of conventional 2D projects multiplied by at least two:

- 3D projects mean double the recorded material – that means double the disc space, double the rendering overhead and double the issues with moving media. Very good disc management is needed, with techniques like Frame Magic™ proving very useful.

- There are issues in off-line. On conventional off-line systems you can't judge depth effects, you can't judge the pace of the project (3D feels better with longer, slower shots), you can't easily see if there are colorimetry, positioning or synchronisation issues between the cameras etc. That all means off lines are guesswork and much more fixing needs to be done in the online sessions. That can mean using a team of VFX, Colour and Editing applications to fix the

problems in the edit or during DI – but that is complex and slow – guesswork again. At the time of writing (March of 2009) the good news is that Stereo3D offline systems are now coming onto the market.

Continued

- Conventional on-line systems struggle with Stereo3D projects. Working 'one eye at a time' means lots of opportunities for errors and using proxy/rendering workflows means lots of time waiting for renders and opportunities for technical errors. Having to rendering Stereo3D adjustments is also a big issue as it uses up large amounts of disc space. Quantel has pioneered Stereo3D post and introduced tools like Pablo, iQ and Sid that work with both eyes simultaneously and can adjust Stereo3D convergence without rendering.

The HPA 2008 engineering excellence award for Quantel Stereoscopic3D post.

Q: Aren't some people arguing that we should wait for AutostereoTV?

A: Yes they are. Autostereo TV means 'no glasses' for example using lenticular technology.

There are many applications for Autostereo displays right now. The first example is digital signage – Stereo3D images grab the eye and it is a huge advantage to have Autostereo televisions in supermarkets, airports, exhibitions, trade shows, railway stations etc. to catch people's eye by running Stereo3D commercials or information.

The second example is in presentations. Imagine if you could open your Mac or PC notebook and make a presentation in Stereo3D. Or have Autostereo Internet delivered content you watch on your computer. Very soon that can be a reality.

Also, demonstrations have already been made of Autostereo mobile phones and handheld media players.

If we could have good quality, low cost, simple to produce and simple to post-produce Stereo3D Broadcasting that didn't use glasses that clearly would be a good thing. However, we haven't yet met those criteria. Autostereo TV is very promising for some point in the future but the smart money today is on systems that use glasses.

There is good momentum from the games console community for active glasses systems and significant investment from the TV set manufacturers for Polarised or even frequency based passive glasses.

Do these really look so bad[9]?

Since 'Broadcast' is now 'anycast' there is no doubt that Autostereo will have an important role to play in some different ways and at some different points in times.

[9] *OK we cheated. One pair aren't for Stereo3D – but you guessed that…right?*

Q: How do Stereo 3D television screens work?

A: The two main types on the market now use either passive polarised or active shutter glasses.

One method involves circular micro-polarisers in a film that can be bonded to a flat panel display:

Passive and active systems

If supplied with side by side stereo3D signal, electronics inside the set create a left and right eye view. When looked at through passive circular polarising glasses, one eye sees the odd and the other eye sees the even lines.

Another method uses TVs with shutter glasses that synchronize with the TV using infrared. The TV displays left and right one after the other. The switching of the glasses prevents the left eye from seeing the right image and vice versa:

There are a number of other schemes that may come to prominence in the next few years.

Q: What are the artistic/technical difference between Stereo3D Film and TV?

A: There are some important differences between working on Stereo3D Film versus TV and also some differences between working with still Stereoscopic photography and moving images.

This is an important topic for Stereo3D Broadcasting because various suggestions are being made about TV by people with experience in working in Stereo3D film or stills. Many suggestions are good ones – but there are some important differences.

Here's a quick round up of just four of the topics – there are many others.

	Stills	Cinema	TV
Shooting parallel vs. converged.	A matter of choice for stills – either can be made to work.	A matter of choice for cinemas – either can be made to work as they can be adjusted in Post.	Shooting converged in live TV requires downstream adjustment.
Managing z-depth over time, via convergence, to avoid viewer fatigue.	Not applicable.	Important – viewers will be watching for over an hour.	Very important – viewers may be watching for many hours.
Non-parallax difference errors (colour, size, skew, image artefacts etc.)	Irritating, but the viewer experiences them momentarily.	Very important, as viewers will be watching for over an hour. Fatigue or even nausea can result.	Critical to keep to a minimum, as viewers may be watching for many hours.
Control over the experience	Viewing conditions may be unknown to the creative team. Viewer can look away or change picture if uncomfortable.	Viewing conditions (size of cinema, seating layout, screen type etc.) are broadly known to the creative team. However, viewer has no control of the experience other than leaving (or moving around a darkened cinema).	Home viewing conditions (size and type of TV, seating layout etc.) may be unknown to the creative team. However viewer has some control of the experience including moving themselves, adjusting the TV, adjusting lighting, moving the TV.

Q: Why are some people concerned about TV viewing distances?

A: As we discussed earlier, some argue that since we can't control what size people's TVs will be and how far away they will sit, Stereo3D will not work in TV. For example this article:

http://blog.mission3-dgroup.com/2009/02/20/why-is-stereo-3d-not-ready-for-broadcast-tv-mission3d-explains/

We certainly need to understand how people will watch Stereo3D TV at home.

While the article itself combines the depth question with other unrelated problems with anaglyph or anaglyph – like approaches (which no one is seriously arguing in favour of as a practical broadcast standard) it does raise some points worth discussing about depth.

Let's go through the pertinent points in the article one by one:

"It turns out for most of us to see in anaglyph stereo 3D - and instantly perceive depth - we need to be using the right pair of 3D glasses with the matching feminine or masculine stereo vision format".

- Possibly so, but no one we know is promoting anaglyph or anaglyph-like broadcasting

"Sam explains that there are three main reasons why 3D will not work in broadcast TV:

1. Chaotic viewing distance

2. Uncontrolled TV display size

3. The variety of analogue, LCD, LED, and plasma display formats"

- The subjective strength of the stereoscopic effect viewers experience is partly dictated by how far they are away from the screen and how big the screen is. However, non-parallax cues (like object size, detail, shadows, colour, detail, relative motion, occlusion etc.) are also very important and screen size has limited or no impact on the effectiveness of most non-parallax cues.

If we create content for IMAX or Digital Cinema delivery, we have relatively controlled viewing environments. The audience isn't walking around and the seating depth and width is fixed. Of course where individual audience members sit in the Cinema varies but there are useful rules of thumb which can help Stereographers during shooting or Post houses during finishing and mastering.

Broadcasters planning Stereo3D services simply need to understand what degrees of parallax are likely to work for the majority of viewers, what is marginal and what is wrong. They will also need to learn how to use non-parallax cues. Viewers will need some simple guidelines about how best to enjoy the service, although most viewers will likely find that out by trial and error anyway.

"One thing we all know is that the further away we go from an object the smaller it gets, so there is a strong and direct relationship between perception of size and distance. What most everyone missed noticing is that the further away we go from a real object, the less 3D depth we perceive. This is the main reason why 3D is not ready for broadcast TV, and may never be".

While depth needs to be understood, Stereo3D TV does not need to be mathematically correct, it needs to be attractive to viewers. The driver for adoption is money, not science.

Continued

In TV programmes and commercials, colorists are paid good money to make colour look pleasing, not mathematically correct. Viewers are not passive receptors. People have color controls on their TV sets which they can turn up and down. There are many kinds of TV sets. Colourists have no control on the final colour experience TV viewers will see but they have evolved methods that work. The same applies for Sound.

Since we manage to transmit TV in ‘chaotic’ colour and sound home environments, we can also do so with Stereo3DTV. Stereo3D test signals can be created. The chairs in my lounge can move and my TV is not cemented into a wall. As a viewer I am capable of finding a viewing position that works.

So long as we can deliver pleasing images *and* the audience gains an understanding of how to best watch Stereo3D there is no definitive evidence yet that this will be an issue and plenty of other evidence that it won’t.

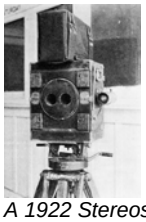
Appendix 2: Stereo3D at the Cinema

The current interest on Stereo3D Broadcasting has been fuelled by the spectacular recent success of Stereo3D in Hollywood.

Stereoscopy has a 150 year history

When I think of 3D I think of the ‘creature features’ of the fifties or the theme park movies of my childhood. However stereo stills cameras were on the market from the 1830’s and the first test moving films were shown very early in the last Century – some say 1902, others 1915.

The first feature length screening ‘The Power of Love’ showed around 1922.



A 1922 Stereoscopic movie camera

The so called ‘Golden Age’ of 3D movies ran from around 1952 to 1955. At that time, the Studios were under attack from TV and were looking for the ‘next big thing’ to lure audiences back to the theatre.

Some classic 3D movies from the 1950s

One widely held view is that 1950's 3D movies suffered from three main problems.

- They were very complex to shoot, (you had no idea what 3D shots would look like until a day or more later) which explains how inconsistent and poor much of the photography was and how some 3D effects are uncomfortable to watch.

- They were very slow and difficult to post produce. Traditional optical and chemical effects are cumbersome enough even with a conventional 2D movie as you have no idea what the effect looks like until it has been printed.

- They were very tricky to project. Keeping two projectors in harmony was very difficult so screenings were inconsistent[10] – plus traditional 3D glasses[11] were uncomfortable to wear. Some audience members often went out with a headache!

Others say that the real problem was that there was a knowledge gap in production and distribution – as the rapid growth in demand got ahead of the numbers of skilled people. In any case, 3D cinema wasn't a really commercial product.

It seems from the 1960s onwards the film 3D market settled into specialist areas like IMAX with the odd high profile side project to a big movie (Amityville 3D, Jaws 3D, Terminator 2) often linked to theme parks and museums.

Things started to change a few years ago. What we used to term '3D' has now become 'Stereo3D' and it is quite a different methodology to the films of the 50's.

As someone involved in conventional Digital Post, it makes sense to me that Stereo3D Digital Post is more agile and less error prone than optical and chemical methods. So the growth in Digital Effects and later in DI potentially makes Stereo3D post quite a bit easier.

Another new tool is Stereo3D digital acquisition. Unlike shooting film, a cameraman or director can view digital on location while it is being shot. Also unlike film, digital doesn't suffer from weave or hop and doesn't need to go through a chemical development process which can lead to differences between the 'eyes'. Modern pioneers of this process include 3ality Digital, Pace and Paradise Effects who between them have a string of successful digital projects.

Finally, digital projection is eminently suited to Stereo3D. Unlike optical projectors, there are no issues with film movement, scratches or dirt. There are now various different digital projection choices[12] that can handle conventional 2D films as well and from what I've seen of them they all look good.

These three steps forward – digital post, digital capture and now digital projection, have removed a lot of the complexities and costs of film.

Stereo3D Cinema now

DreamWorks have announced all their animated movies will be 3D from 2009 and with many other new stereoscopic projects in the pipeline, demand for Post services is growing and growing fast.

Quantel Post customers have already played a part in digital 3D. For example, in Ghosts of the Abyss, Aliens of the Deep (James Cameron) Spy Kids 3D and Shark Boy and Lava Girl (Robert Rodriguez).

[10] There were single strip systems that solved the issue of projector synchronisation but at the expense of introducing other complexities.

[11] Typically Polarised, not Anaglyph.

[12] RealD (passive polarised glasses), Dolby (passive frequency based glasses) and McNaughton (active glasses) are three well known examples.

Every month brings announcements of new projects. As well as the creative push, the obvious commercial angle is that good 3D movies enjoy a premium at the box office. Interestingly, 3D movies also can't be shown on conventional VHS, DVD or Web which is a new angle on anti-piracy.

"Hannah Montana & Miley Cyrus: Best of Both Worlds Concert" smashed box office records

Watching modern Stereo3D is a different experience from the preconceived idea of uncomfortable coloured cardboard glasses used on comics. Today, it's much more like wearing comfortable Polarised 'sunglasses' and there are also non-polarised frequency based glasses. Both can give excellent results.

It's a booming industry that will help provide content for Stereo3D film channels.

The six IBC 08 awards for Stereo3D

Innovation of the Year' Award from Producción Profesional

Appendix 3: Stereo3D Terminology

Here are some common terms you may come across when you hear Stereo being discussed:

Accommodation
The ability of our eyes to refocus at a new point of interest.

In normal vision, the processes of focusing on objects at different distances (accommodation) and convergence/divergence (the angle between the lines of sight of our eyes) are linked by muscle reflex. A change in one creates a complementary change in the other. However, watching a stereoscopic film or TV programme requires the viewer to break the link between these different processes by accommodating at a fixed distance (the screen) while dynamically varying eye convergence and divergence (something we don't do in life) to view objects at different stereoscopic distances.

Anaglyph
A type of stereoscopy in which the two pictures are individually coloured and then superimposed as a single image rather than two separate images. Each eye sees only the required image through the use of coloured filters (e.g. red/green, red/blue or red/cyan). Anaglyph glasses have been popular over the years for viewing 3D comics and some 3D films (particularly on VHS and DVD).

A major factor in producing good quality stereoscopic content is that the only difference between the two eye views should be horizontal parallax. A fundamental problem with Anaglyph is that it is based on presenting the brain with different colours in each eye. It is strongly argued that this makes Anaglyph inherently tiring to watch over extended periods of time. Additionally, accurate colour representation is a major issue.

Although Anaglyph itself has fallen out of favour for quality Stereo work there is modern work going on with other somewhat anaglyph like colour based systems (e.g. Trioviz or ColorCode-3D)

Blur Roll-Off (Blur Gradient)

One important non parallax depth cue in the real world is that images are sharpest for objects in focus and less sharp for objects not in focus. When colour grading a Stereo3D project, it's sometimes useful to use compositing techniques to alter the sharpness of objects.

Breaking the Frame
Stereo objects in front of the screen plane (negative parallax) are problematic if they intersect the edge of frame, as contradictory depth cues are sent to the viewer. Essentially one cue is saying that the object is in front of the screen and another is saying that the object is behind it.

This problem can be reduced in Post by a technique known as a 'floating window'. This involves applying a partially transparent mask on the left of the left image and on the right of the right image, reducing the strength of the cues on which ever side the object is breaking frame (and simultaneously if there are objects breaking frame both left and right).

Another kind of issue is caused by objects moving backwards and forwards over the edge of frame. As an object moves off the edge of a screen one stereo camera signal is lost before the other. The result is that the stereo signal temporarily 'switches off'. This can sometimes be solved by sizing up both images in Post, causing the object to move off screen altogether.

Objects breaking the frame aren't necessarily a problem. It happens in IMAX all the time and also is common in conventional stereo films - the audience is encouraged to concentrate away from such an object by well thought out shooting.

Cardboarding
Lack of true 3D feel to a shot making it look like it is made from cardboard cut-outs. This is also referred to as Cut-out Planar Effect. Caused by inadequate depth resolution due to an incorrect matching between the focal length of the recording lens (or CGI camera) and the interocular distance between the cameras.

See: Interocular

Checkerboard
A display format where left eye and right eye images are combined into a single image like the positions of the black and white squares of a chess board. Also known as 'Quincunx'.

Convergence
In human eyesight, the ability of our eyes to divert eye optical axes horizontally in an inward direction. The convergence 'near point' is the closest point which is still possible to perceive one image. In practice, the eyes can easily converge inward but have much less ability to diverge outward, as it is something we don't do in life and only when looking at 3D images that have positive parallax beyond the individual human interocular.

In cameras – 'toeing' of the cameras (to simulate the eyes converging) focusing on a depth point in the scene, either in front of, behind or at the point of interest.

The 'convergence point' is where the axes of toed in cameras align on the Z-axis. Convergence can be adjusted in Post by horizontal movement. Note that sometimes the term 'vergence' is used to describe both convergence and divergence.

Convergence pullers are camera-crew members on a Stereoscopic shoot who are responsible for setting up and shifting the convergence during a shot.

See: Parallax

Depth Grading
A post production process where negative and positive parallax convergence and divergence are adjusted. This is not only a creative tool used to place objects on the Z axis but also a way to ensure that stereoscopic content can be comfortably watched on the screen size it is intended for. For example, in a Post suite the Director may be viewing a film on a small projection screen but the final delivery format may be a large theatre or IMAX.

In practice the eyes have little ability to diverge (up to one degree is considered the rule of thumb) and this is especially a consideration in depth grading for very large screens with positive parallax images, where the distance between the left and right representations of an image may be very widely spaced.

Sometimes the term Depth Budget is used to refer to the combined value of positive and negative parallax and expressed as a % of screen width.

See: Parallax

Floating edges or Floating Window

See: Breaking the Frame

Ghosting
Artefacts typically caused by signal leakage (crosstalk) between the two 'eyes'. A secondary 'ghost' image can be seen. There are several possible causes that can introduce the problem during acquisition, post production and display. One reason can be high contrast levels between an object and its background.

Gigantism
Confusing Visual cues in a stereoscopic scene that can make an object appear to be the ‘wrong’ size i.e. the impression of strangely enlarged size of objects. This is due to the choice of interocular distance relative to the focal length of the camera lenses, e.g. shooting with an interocular distance much less than adult human eyesight can make a figure appear to be a giant.

See: Miniaturization, Interocular

Hypostereo
Using closely spaced cameras (e.g. less than 50 mm interocular) which record less stereo effect than the eyes can see. Such a small interocular distance can produce the effect of gigantism. If standard cameras are used, the minimum interocular distance is typically limited by the thickness of the cameras so a mirror or beam splitter system is often used, enabling interoculars down to millimetres.

See: Gigantism

Hyperstereo
Using widely spaced cameras (e.g. beyond 70mm interocular) which record more stereo effect than the eyes can see. Such a large interocular distance can produce the effect of miniaturization. Also used in order to achieve the effect of more stereo depth and less scale in a scene.

For close up work (e.g. miniatures etc.) special Interocular camera set ups of 5mm or less have been used (known as Hypostereo).

For stereo effects on very long shots (e.g. landscapes) Interocular camera set ups of several meters have been used (Hyperstereo). One extreme example of Hyperstereo is from cameras mounted in space to record the Sun in 3D.

See: Miniaturization, Interocular

Interocular distance
The distance between the centres of the lenses of two recording cameras. A typical distance would be 63.5 mm (approximating average adult eye layout).

The term ‘Interaxial’ is sometimes also used interchangeably with ‘Interocular’
(when referring to eyesight , ‘Interpupillary’ is often used)

Keystoning
The result arising when the film plane in a camera or projector is not parallel to the view or screen, leading to a trapeze shape. On a stereoscopic image, where the cameras are 'toed-in' so that the object of interest coincides when viewed, there can be some mismatching of the outlines or borders of the two images. Techniques like corner pinning can be use to help correct this.

Kid Mode
Children have smaller inter-pupillary distances than adults. Some argue that Stereo3D TV sets could be fitted with some kind of adjustment to compensate for that.

Lenticular
A method of displaying stereoscopic images without glasses, using thin vertical cylindrical lenses and a special interleaved left and right eye image format – a similar technique to Parallax Barriers except that there are no opaque slits.

See: Parallax Barrier

Miniaturization
Confusing visual cues in a stereoscopic scene that can make an object appear to be the 'wrong' size i.e. the impression of being strangely reduced in size. This is due to the choice of an interaxial distance of greater than 63.5 mm relative to the focal length of the camera lenses e.g. shooting with very widely spaced cameras. Subjectively this makes the audience feel like a giant looking at tiny objects, which is why miniaturization is sometime referred to as Lilliputianism.

See: Gigantism, Interocular

Orthostereoscopic
A one-to-one condition where what is being displayed is the same as the 'real world'. For example IMAX 3D is often shot with parallel cameras spaced at the average human adult interpupillary distance (approx 63.5 mm) and with wide angle lenses that closely match an audience member's view of the screen.

Over- Under
A display delivery format that combines the left and right eye images into a single image by squeezing the two images vertically. For display, the images are subsequently unsqueezed. Also sometimes known as 'top and bottom'.

Parallax
This refers to the separation of the left and right images on the projection device or display screen.

Positive Parallax puts an object behind the screen (on screen objects in the left eye image are to the left of the same objects in the right eye image).

Negative Parallax puts an object in front of the screen (on screen objects in the left eye image are to the right of the same objects in the right eye image).

Zero or neutral Parallax puts an object on the screen (on screen objects in the left eye image are overlaid on the same objects in the right eye image).

The only difference between stereo cameras should be parallax or angle between the axes of the lenses as in Camera Convergence – anything else can disturb the stereo viewing experience. This requires close attention, so that the cameras are set-up the same and with the same filters. Colour differences, skewing, vertical misalignment, differential weave and hop, lens flares, poor VFX fixes, scratches and dirt can all cause problems.

Fast cuts between shots with strong positive and strong negative parallax can be unsettling in some circumstances. This is because the eyes and brain are being asked to jump uncomfortably quickly between positions and then make sense of the result. This can be mitigated by the use of 'handing off' – dynamically changing the convergence of an outgoing shot in relation to an incoming shot. Another method of dealing with this is trying wherever possible to cut between shots that are somewhat close in parallax.

Vertical parallax is a vertical offset between stereo images and is very uncomfortable to watch – so it is necessary to remove during post production.

Note: The term 'Parallax' is sometimes used interchangeably with 'Congruence' or 'Disparity'

Parallax Barrier Displays
A form of glasses-free (Autosteroscopic) display that uses a vertical grating and a special interleaved left and right eye image format that results in the left eye seeing the strips from the left eye image and the right eye only seeing the strips from the right eye image.

Pulfrich effect
Horizontal motion that can be interpreted as binocular depth. A stereo effect which is produced when 2D images moving laterally on a single plane are viewed at slightly different times by each eye.

Psuedoscopic
If a stereoscopic signal is reversed (e.g. each eye is being fed the opposite eye signal or if there is a one frame offset between each eyes) a strange 'punched in' effect appears. This is also referred to as inverted stereo or reversed stereo.

Stereoscopic Window
The amount of Stereo image available to the viewer is dictated by the frame surrounding a stereoscopic image, e.g. the size of TV or projection screen. This boundary is called the Stereo Window. Depending on their Parallax objects will appear either in front, at or behind this Window. IMAX has the largest window.

Side By Side (SBS)
A display delivery format that combines the left and right eye images into a single image by squeezing the two images horizontally. For display, the images are subsequently unsqueezed.

See: Over - under

Zero Parallax
An object in a stereo scene that has no horizontal parallax offset is said to be at zero parallax. The zero-parallax position (sometimes referred to as the point of convergence) is often used for the object of interest in the shot, therefore establishing zero parallax is an important creative decision in guiding the audience. For example on a Stereo3D Broadcast, the director may choose to have text at zero parallax which will locate it on the screen plane. It can be adjusted in post production by the process of convergence.

See: Parallax

2D+Depth (also known as 2D+Z)
A way of describing a single image along with depth data from a scene.

2D+DOT
A way of describing a single image along with depth, occlusion & transparency data from a scene

2D+Delta
A way of describing a single image (e.g. left eye) along with the difference between the original image and a second view (e.g. right eye).