Stereo 3D kicks off

As we have seen in David Fox's report from the recent 3D Masters conference (*pages 6–10*), the 3D TV ball is rolling – and fast. In the UK, Sky is well ahead in this game and has been transmitting football in 3D for some time, with plans to launch a full 3D service in the autumn. Ex-Pebble Mill cameraman Dave Wilkins has been involved with the Sky 3D football coverage over the last six months and explains for us how it works from the operator's viewpoint.

The story starts back in November 2008 when three 3D rigs, recording independently, were tested at a Champions League game at Liverpool. One camera was placed in the traditional Camera 1 position, another on the six-yard box behind the goal and the third low by a corner. Each camera shot part of the game at various lens angles and then the footage, along with material of boxing, ballet and the runner Usain Bolt, was used to produce a demo tape. On this early test, the *convergence point* and distance between the cameras (or *interaxial*) were only manually adjustable for predetermined fixed focal lengths and so it was not possible to zoom (*see 'How 3D TV works' on page 15 for technical info*).

A year later and things had moved on. By November 2009, Telegenic had re-equipped one of its units, T5, with 3D 'active' camera rigs and control systems designed by 3Ality Digital in California. These were tried out at an Arsenal reserve fixture at Barnet FC. Manufactured to an extremely high tolerance in Germany, to 3Ality's design, the rigs are motorised, with remote control of convergence and interaxial separation. This 'active' system allows for live zooming across virtually the whole range of the lens.

The rigs, mounted on Vinten 950 panning heads, come in two standard configurations: TS2: mirror (or beam splitter) and TS4: side-by-side.

Done by mirrors

The mirror rigs use two Sony T-1500 block adaptors (which require the HDC-1500 camera body to be within a few meters of the rig), with one camera mounted horizontally (which can move from 0 to around 12cm of interaxial separation) and the other fixed vertically looking down. A semi-silvered sheet of glass placed at 45 degrees in front then works like a prompter with the horizontal camera looking straight through and the vertical seeing the reflection off the front. One problem with this rig is that the lens range is limited to a focal length range of approximately 11mm to 110mm. This is because wider than 11mm and the mirror box is visible in frame, and above 110mm the quality of the reflective surface of the mirror becomes an issue. These rigs are better suited for closer action as the interaxial distance can be reduced to zero with both cameras looking along the same axis. However, due to the mirror, you lose a stop of light.

▼ Grant Rosson operating a mirror-rig in a low corner position using a specially modified Ronford-Baker mount

◀ Camera One at Wembley using a side-by-side rig

Side-by-side

The side-by-side rig has two full-size Sony HDC-1500s mounted on a sled alongside each other. The left camera is fixed while the right can move along the sled. The cameras can be separated further apart than on the mirror rigs, often between 12 and 30cms, and are better suited for subjects that are further away (>20m) and/or on longer focal lengths. It is important there is no foreground interference but the advantage is that the lenses don't need their zoom ranges limited.

Synchronised lenses

Lenses are standard 22:1s and each pair goes through a 16-point line-up throughout their zoom range to produce a look-up table (LUT) so that any inconsistency in alignment, distortion or aberrations can be eliminated. The motorised rig ensures that lens length, focus, iris and zoom (known collectively as FIZ) are linked as closely as possible so that the images stay the same size from the beginning to the end of the zoom range. Any discrepancy can produce discomfort to the viewer or break the stereo illusion of depth.

The software also enables the convergence operator to change the interaxial separation and the convergence point by altering the FIZ parameters. It is these adjustments that create a greater or lesser stereoscopic effect and they need to be set whenever the lens angle is changed. It is pointless zooming past the convergence point if they aren't adjusted.

New job descriptions

At the moment there is one *convergence operator* or 'puller' for each camera. They are responsible for the building and preparation of each rig with the camera crew and can be thought of as the 3D equivalent of a focus puller. They adjust the 3D shot volume and depth for a camera rig in real time as directed by the stereographer.

The *stereographer* is at the core of the 3D production. He or she is central to the whole 3D 'experience' and will interpret the director's intentions, coordinate the 3D settings made by the 3D pullers and ensure that the 3D being transmitted conforms to the broadcaster's 3D compliance.

A separate *3D engineer* oversees the set-up of the 3D video signal flow including 3D rig alignment, and adjustment of 3D image quality and lens attributes to ensure that all rigs are working within specification during the production.

Camera positioning

For that first game with the 3Ality rigs at Barnet, the three available rigs were placed at one end of the pitch with one directly behind the goal and the other two low in the corners. This gave a good impression of depth as the play came towards the cameras, but the lack of a camera position on the halfway line was thought to be too radical a shift from normal presentation for audiences. Subsequent matches reverted back to Cameras 1 and 2 on the halfway line for the main wide angle and close play coverage.

In more recent games, as more rigs have become available, other cameras have been placed, depending on access, in any combination of corners, behind one of the goals and, when possible, on the six-yard position.

After a few weeks of successful trials, Sky decided to go forward and commissioned Telegenic to build a dedicated truck fitted out by Sony using the 3Ality system. The new unit, T18, was used for the first time in earnest at Liverpool FC at the end of March 2010.

There are currently three of each type of rig available, which gives a certain amount of choice as to which type to use in each position. Another unit, T19, has since been commissioned which will come into use in late summer. This will make it possible to 'pool' all the rigs giving maximum flexibility with regard to the most suitable rig for each job.

> *"the side-by-side cameras can be separated further apart than on the mirror rigs and are therefore better suited for subjects that are further away and/or on longer focal lengths"*

Each ground is different

As we moved on to bigger grounds and Premiership matches, the need for careful planning of positions for 3D coverage became very apparent. It was obvious that lower positions worked best but the existing gantries at most grounds are just too high or not big enough to take an extra two cameras, in addition to those already there for 2D coverage. Even when it is planned that, say, a mirror rig would be best from a 3D point of view in a particular position, this may not be possible due to its height blocking the view of spectators. At some grounds – Chelsea, for example – there was already a lower slung gantry for the centreline Camera 3, and this has been extended to allow another two camera positions. At other grounds the solution may be to use similar slung platforms with camseats over vomitories or the front of the first tier. If necessary, the 3D coverage may be moved to the other side of the ground from the 2D coverage.

Physically getting the rigs into position should not be taken lightly either. Both types of rig are transported with their cameras and lenses in position, making them quite heavy (around 55kg) and awkward to manoeuvre. Some precarious situations can be made safer with careful attention to hoisting positions and clearances onto platforms etc.

2D view

The actual 3D image is not available to view at the camera end. On each rig, only one of the cameras or 'eyes' is viewed and so it is actually not that radically different to operating in 2D. The other 'eye' is available on return though, and this is important for looking out for 'edge violations'. This is the term used if there is something on the edge of one frame that isn't in view on the other camera of the pair. The brain gets confused trying to make sense of where it should be in 3D and this breaks the illusion. Much effort is made when rigging to remove any potential obstructions (scaffold poles etc) but there will often be some immovable objects. Seeing the corners from Camera 1 can often be problematic especially with other cameras alongside. The director is made aware of these issues during the facilities check and will (usually!) cut to another camera when play approaches the problem area.

3D protocol

The number of cameras used per match has so far largely been determined by the number of rigs available but will unlikely ever be as many as in 2D coverage. The number of cuts is reduced too, allowing the viewer to absorb the depth seen

▲ Convergence operator's control panel

> *"existing gantries at many grounds are too high or not big enough to take an extra two cameras in addition to those already there for 2D coverage"*

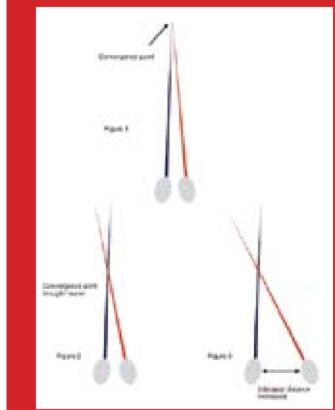
How 3D TV works

Stereoscopic 3D artificially recreates the fixed interocular separation which exists between the human eyes; this enables the brain to form a 3D world from two slightly different angles of view. When describing this separation on a 3D camera rig it is referred to as the *interaxial*.

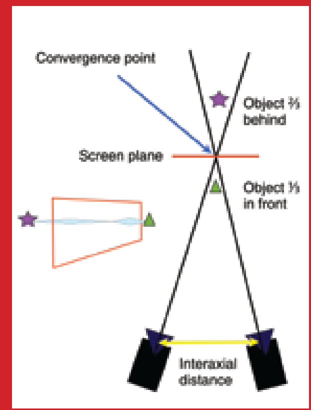
Unlike the human eye we are able to adjust the focal length of the lenses on 'active' 3D rigs; this means the interaxial separation needs to be adjustable to control the depth perceived by the viewer (*see Figure 1*).

In addition to the interaxial we are able to control the *convergence* of the cameras. Convergence determines where the objects are within the 3D space and is the point at which our screen plane exists. Placing the convergence behind our object of interest will, when viewed, make the object seem to 'float' in front of the screen plane.

The *screen plane* is the term used to describe the only fixed point within the 3D world, the front of the actual TV screen. As a basic rule, when creating 3D for broadcast TV, we aim to have 1/3 of the 3D image in front of the screen plane and 2/3 behind (*see Figure 2*).



▲ Fig 1



▲ Fig 2

When the two outputs of the cameras are combined for viewing, the separation of the objects within the image changes, dependent upon the objects' position within the 3D space, as controlled by the interaxial and convergence. This separation is called *parallax* (*see also pages 9–10*).

As a rough guide, the maximum positive parallax of an object at our point of 3D infinity is 2% of the overall screen width and our minimum negative parallax is –1% (Sky have limited this to –0.5% to protect for graphics and the channel ident DOG (or digital on-screen) graphic).

Extracted from 3D in-house training guide by Adam Sculthorp, Senior Stereographer at Telegenic within the 3D frame and the extra visual information. As the viewer has 'stereoscopic' information, it is much easier to see what is happening utilising exactly the same principle that allows us to recognise a person from a distance.

Panning speeds need to be kept fairly slow so that the brain doesn't overload with information. Obviously, the ball has to be kept in shot, so using the whole of the 16:9 picture and letting the ball run closer to the edge of frame allows the panning speed to be slower. There is no need to protect for a 4:3 safety area as 3D will only be viewed in wide screen 16:9.

Overuse of, and particularly rapid, zooming on shot can cause a major issue. The computer controlling the optical alignment with key frames from the LUT only compares the two pictures when the system isn't receiving zoom control information, so

"rigs are transported with their cameras and lenses in position, making them quite heavy (around 55kg) and awkward to manoeuvre"

the analysis stops while zooming. Also, adjustment of the interaxial separation and convergence by the puller to create the 3D effect is controlled by hand and driven by motors within the rig so there can be a slight delay in this operation.

Those of you familiar with watching football will be used to big close-ups of players. The lenses we use at the moment have 22x zooms, not long enough to get in tighter than a long shot. But there is so much information in the frame that the audiences seem to accept the lack of close-ups. The director does, however, have a feed of the 2D touchline camera through a 2D–3D converter to use if necessary.

Similarly, although there are no 3D cameras positioned on the 18-yard line, the 3D director has access to the 2D output for replays if these are considered necessary. Sky has decided that no more than 10% of a native 3D production can contain images sourced in 2D. Similarly, the 2D production may even have output available from the 3D cameras, taking the output from one of the pairs if they have captured something more clearly than the 2D coverage.

Transmitting the pictures

For transmission, Sky are using a 'frame compatible image' where the images from the left and right cameras are squeezed horizontally to 50% of their original size and placed as a single side-by-side image within a 2D HD picture. The vertical resolution remains the same. This can be transmitted over the normal HD broadcast infrastructure and received by a standard HD receiver to be decoded by a 3D capable television. Squeezing the left and right images has generated some debate as to whether the resulting 3D image received is really HD as the horizontal resolution is halved, although my own view is that this is not actually noticeable in practice.

First live 3D broadcast

On 31 January 2010, the Premiership game between Arsenal and Manchester United from the Emirates Stadium became the first ever live 3D TV sports event to be broadcast to a public audience. It was shown in just a handful of selected pubs, but by the end of the season you could watch 3D games in over 1000 venues. Sky's dedicated 3D channel was successfully launched with the Manchester United v Chelsea match in April and offered weekly 3D Barclays Premier League matches to commercial premises throughout the climax of the season. From May, coverage was expanded to rugby union as Sky 3D offered live coverage of the final and one of the semi-finals from the Guinness Premiership, plus the international match between England and the Barbarians.

For the 2010/11 season, Sky will be covering over 70 3D Premiership football games in the UK. Further sports (including golf, cricket and rugby league) will be added in the coming months, ahead of the launch of Sky 3D to residential customers later in 2010. Ultimately, the channel will offer a mix from Sky One, Movies, Sports and Arts.

Many thanks go to Adam Sculthorp, Senior Stereographer at Telegenic, for some of the more technical information in this article and for allowing the use of his overview of Stereoscopic 3D, extracted from his in-house training guide.

▲ *Dave operating Camera One at Wembley*

▲ *Grant Rosson operating a mirror-rig on a modified Ronford-Baker mount*

Fact File

Dave Wilkins joined the BBC in 1978 to work at Pebble Mill in the studios, on PSC and OBs, until going freelance in 1997. He works regularly for Sky Sports on their football coverage, and has been extensively involved with their trials and transmission of 3D footage.
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Adam Sculthorp started his career as a cameraman 12 years ago, joining Telegenic in 2001. He has always embraced new technology, including the launch of the UK's first HD OB truck in 2002. When Telegenic started to experiment with 3D, Adam helped develop this new technology and is now working full time as a stereographer.

Telegenic launched the world's first dedicated 3D outside broadcast unit T18 in March this year, a second unit T19 joined the fleet in July.
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Useful apps
To help calculate parallax and separation, download: the RealD Professional Stereo3D Calculator (£180); 3D Movie Calculator (£18.50); IOD calc (£30); or 3D ST (£7.50), from Apple's App Store for iPhone, iPad or iPod Touch.