



The essential stitch guide...

or how to produce 360° pictures

Many of us are just beginning to think about the arrival of virtual reality (VR) as a potential new source of production opportunity. But what does shooting 360° really entail? Figment Productions, based in Guildford, Surrey, have been involved with VR longer than most, with extensive experience of shooting for interactive experiences – here, film-maker and creative producer **Steve Cholerton** explains what he has learned from his many 360° shoots.

Being an occasional shooter, rather than a certified DoP, I must confess to being a little cavalier about my first 360° shoot. I figured that since the camera, in this case a GoPro Hero rig consisting of six individual GoPro cameras arranged in a kind of extrovert Rubik's Cube, was going to shoot in all directions, well, at least I wouldn't have to worry about framing. I'd basically just press the record button and hide behind the nearest wall. And that, pretty much, is how it turned out.

Except that, when I got back to the studio, I realised that achieving usable 360° footage requires a bit more effort than simply choosing a peachy vantage point and hitting the button. First, I had to learn to stitch the darn stuff together. Six cameras, six bits of video. Higher-end rigs like the Nokia OZO and the Google Odyssey will do this bit (the stitching) automatically, but it's very instructive for any would-be 360 camera operator to familiarise themselves with the process. The shot, you see, is only as good as the stitch. In a sense, stitching is the new framing, insofar as you want to avoid bits of the environment that are going to mess your shot up. So, knowing how to manually stitch, or at least being familiar with the concepts involved, is probably a good place to start.

All about the essential stitch

With new cameras and stitching software hitting the market every month, Google becomes your best friend when it comes to choosing the appropriate solution. In my case,

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a basic search suggested two possibilities to stitch GoPro footage – PTGui and Autopano Video. Autopano is owned by a company called Kolor that was acquired by GoPro in 2015, making it an obvious choice. That was the easy part. Having purchased the software, I turned to that fount of all technical knowledge, YouTube, where, over the course of several sleepless nights, I learned the full horror of the manual stitch. Bear in mind that if you're using YouTube, or the internet generally, to get to grips with VR, you need to watch out for obsolete videos and blogs. The VR sector is so fast-moving that the cameras and stitching software are constantly being updated. After a few false starts, I learned to keep my searches recent and to check that the tutorials I was using referred to the latest iterations of firmware and software.

One early lesson I learned was the difference between 360 video and VR. Frankly, I was a bit disappointed to discover that, from a VR purist's point of view, what I'd been shooting was not actually VR. It was merely 360 video. VR, you see, has to be as good as its name – virtual reality. And reality, as we all know, is 3D. Hence, true VR cameras capture video in stereo, with multiple left and right lenses capturing the landscape twice, just as our eyes do, to be recombined in the headset later to create a sense of depth. Without this vital element of immersion, it might still be a fascinating wrap-around experience, but it isn't VR.

Nevertheless, whether it's VR or 360 video, the stitching process is the same and there are some universal truths that will probably remain valid for a few more years. One hard truth is that any algorithm that automatically stitches images together will not give perfect results every time. Yes, Autopano and PTGui have templates for most VR camera configurations, but from frame to frame, things are liable to go awry. Stitching algorithms use things called 'control points' to work their magic. These are points in the shot (clumps of pixels really) that are visible to two or more lenses – in other words, the bits that appear in overlapping areas. By matching



Testing the Google Jump 360 camera at Kew Gardens

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Stitch lines are like fault lines in the Earth's crust, liable to erupt at a moment's notice with a double image, or a ghost, or a horrible jutting chin where someone's face has been imperfectly duplicated in two lenses.

these up, the computer is able to stitch two separate images together, slowly building up a 360-degree panorama. The annoying thing is that the control points which work for one frame may not work for the next. From moment to moment, the relationship between objects changes – people walk past, trees sway in the wind, inquisitive little kids approach the camera and drool on the lens. And if, for some crazy reason, you've decided to move the camera, say on a drone or the back of a motorbike, or attached to your helmet while you merrily ski at Aspen, then all bets are off. Be prepared to see an ugly ripple (the stitch line) moving like a subterranean whip through the ground.

Hence, the first lesson for the aspiring VR DoP is to mitigate these effects by the careful placement of the camera and by giving due consideration to what the heck might happen while you're hiding behind the nearest wall. For instance, you should know that, for most VR cameras, there are such things as 'action areas' – parts of the panorama where action is captured within the frame of a single lens, without any overlap by adjacent lenses. Action areas are therefore visual regions that are not bisected by a stitch line. Stitch lines are like fault lines in the Earth's crust, liable to erupt at a moment's notice with a double image, or a ghost, or a horrible jutting chin where someone's face has been imperfectly duplicated in two lenses. Trying to fix these stitching problems is a bit like playing whack-a-mole. Fix one dodgy stitch and another one pops up somewhere else. You will never get that time back. So, as far as possible, try to keep the action within these clean areas – carefully block actors so they remain centred in a single lens, or if you're a documentary maker, try to anticipate the movement and behaviour of your subjects so they don't stand between two lenses, on a potential stitch line.

Keep your distance

Another key takeaway is not to let anyone, or anything, get too close to the camera. As objects approach the lenses, the result is what's known as parallax error. Simply put, the closer something

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FIGMENT PRODUCTIONS

One of the most experienced VR production companies in the country, Figment Productions (based in Guildford, Surrey) specialises in CGI and Visual FX, virtual reality and interactive experiences. Clients include international visitor attractions and theme parks, museums, cultural exhibitions and corporate enterprises. Flagship projects have included the Galactica VR rollercoaster at Alton Towers and Derren Brown's Ghost Train at Thorpe Park, encompassing a mixture of filmed VR and CGI. Other recent projects include a VR film for the All England Lawn Tennis Club, depicting the 2016 Championships shot on the Nokia OZO, and commercial work including medical tools using VR with haptic feedback, group learning with HoloLens MR (mixed reality), and a showcase for Samsung Gear VR, which takes you inside an operating theatre to witness keyhole heart surgery. The demand for VR shows no sign of abating, as more companies become aware of the educational, cultural and entertainment value of 360° immersion.



Exposure

For most VR cameras, even the higher-end ones, there is limited control over features such as aperture, shutter speed and ISO. Most VR cameras come with a set of recommended default settings – and it's generally best to stick to these.

The question of exposure is a ticklish one. You can't expose each camera lens separately or the stitch lines will be too apparent. So, the idea is to find an aggregate level of exposure that works for most of the scene, or to decide which area is most important and expose for that, potentially at the expense of a blown-out sky or deep shadows elsewhere in the shot. There is some leeway in post-production to drag the exposure up or down, or to pick a 'hero' camera and use that as an anchor for all the others. But generally speaking, a nice even exposure is your best bet.

Sort it out in post

These considerations aside, it's fair to say that VR shifts responsibility for the shot from production into post-production. This has been a trend for some time, but in VR it reaches a new zenith. This is because, on most shoots, no matter how hard you try, there will be things you can't adjust on the day. For instance, since you're shooting in 360 degrees, there is nowhere to place a lighting stand, or to hide a boom pole, or a boom operator, or, in fact, any crew member. Anything that happens is in the shot. Which is to imply that you can have a crew, and lights, and boom poles, and you can even stand there and keep an eye on the camera so that some snotty-nosed kid doesn't make off with it – but you will have to remove all these elements using a compositing programme afterwards.



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gets to the camera, the more apparent it is that each lens sees the object differently. Ironically, this is also the basis of one of VR's greatest attributes – the ability of certain higher-end cameras to shoot in 3D. But at the lower end of the market, the result can be a jaggedy mess – a kind of video cubism that Picasso might appreciate but your client probably less so. How close can your subject get to the camera? One metre is a good rule of thumb, although as long as the subject stays within one lens (a single action area), you might be able to allow them a little closer. Whatever rig you're using, definitely do a few tests before you commit to a big budget shoot.

Screenshot capturing the 2016 Wimbledon Championship on the Nokia OZO for the Wimbledon Lawn Tennis Museum



For this reason, I am forever shooting 'plates' (or empty shots), which I literally use to plaster over the unwanted bits. If the camera doesn't move position, then it's relatively easy to simply move the crew or equipment a few metres to the left, shoot a plate and then move them back. Plates are then used like jigsaw pieces to complete the puzzle of the full panorama.

The first plate you'll shoot if you're starting out in VR is the nadir – the part directly below the camera where the tripod is. The nadir problem perfectly illustrates the challenges of VR. When you first pop on a VR headset to examine the stitch and inevitably look down at your feet, you will see a distorted mess, composed of bits of tripod and grass. Tripods are parallax problems on steroids. It is for this reason those first plates will be of the ground – literally photographs of inconspicuous bits of tarmac and gravel. On one occasion, an elderly lady, whom I sensed was ordinarily reserved, was so intrigued by my painstaking downward photography that she felt compelled to cross the street to ask what I was doing. A charming 20-minute conversation followed, which bridged the technological generation gap. After explaining to her what a VR headset was, how the camera worked and what a nadir was, my new friend promised to go and see our VR film featuring that dishy Andy Murray. VR had a new convert. Job done.

Patching the panorama

But to reiterate: high-end VR seldom uses a full 360 degrees and often requires patching up the panoramic image. Even at entry level, you'll often be bodging the camera up against a wall, aiming it outwards at your intended subject. Later, in the headset, you'll see the wall bulging and bending like a scene from a low-budget Doctor



In a sense, stitching is the new framing... insofar as you want to avoid bits of the environment that are going to mess your shot up.

Strange. The wall will have to be replaced and manually stitched. A decent high-res photograph or looped bit of video is usually sufficient, replacing the offending section in exactly the same way as you patch the nadir. There is a range of apps that can easily achieve this, including the stitching software mentioned before, and if that proves too tricky, good old Photoshop can do the trick. A simple mask and replace of the background is often all you need to render a wonky stitch immaculate, as long as nothing crosses that particular bit of the panorama. At the higher end things can get a little more exotic. You might find yourself comping in a separately exposed sky, or replacing whole areas of the panorama to conceal the crew, or adding a CGI set extension, or dropping in an actor filmed on a green screen, using applications like After Effects or Nuke. When shooting in VR, one is often shooting with these post-production processes in mind. On a recent OZO shoot with DoP Ashley Meneely for Derren Brown's VR Ghost Train, we literally draped large areas of the set in green cloth and then spent ages hiding the lights required to illuminate them.

A quick word on moving the VR camera: tracking shots, steadicams, jibs and the like. It is generally accepted that since the user typically does not move when watching a VR film (they're usually seated or standing in a fixed spot), the impression of movement can be disconcerting.

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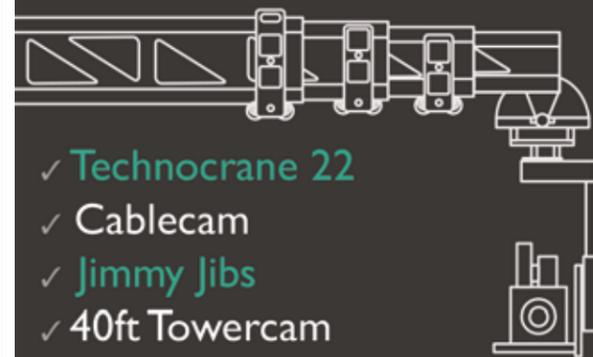
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Reactions can range from “Hey, wow, this is cool!” to mild nausea to a full-blown ejection of lunch. This is because your body is anticipating some level of g-force based on the information it’s receiving from your eyes. When that doesn’t happen, stomach-churning compensatory forces sometimes kick in, with distinctly antisocial results. Hence, it’s become standard practice to ensure that acceleration is steady, rather than sporadic, and that the speed of the moving camera is constant rather than variable. Think pleasant river barge rather than careening speedboat; think cruising down the highway on a Harley rather than navigating chicanes at Silverstone.

Real VR is 3D!

The GoPro Hero rig is a great tool to learn with, but it was when we started shooting on higher-end gear, like the Nokia OZO and Google Jump, that things got really interesting. These cameras go beyond 360° video to shoot in full stereoscopic 4K or 8K splendour. They achieve this feat at the cost of a longer and more convoluted workflow, albeit much of this automated. The Jump, for instance, requires you to upload your rushes for cloud-based processing. A couple of days later, you’ll get the stitched shots back, which is pretty convenient – just click on a link in your inbox, preview and download them. If you hire an OZO, the camera may well come with a technician, who will set up a base station on set where the director or DoP can preview a rough stitch of the shots they intend in the headset. This looks very cool. As a DoP planning to offer VR, familiarity with one or more of these cameras and processes is essential.

Searching for a VR grammar

One last point worth mentioning is film grammar, which for a VR practitioner is a brave new world. In traditional film-making DoPs shoot for the edit, building sequences out of wide, medium and close-up shots. But the shift from 2D films viewed on a screen to panoramic films seen through a headset is changing all that. A panoramic stereoscopic video camera is essentially a proxy for a human head. The user’s head is literally where the camera is, from which position the viewer is free to look in any direction. To put it another way, VR shots are effectively point-of-view shots, but with a difference – in a traditional film, the film-maker decides on the point of view, whereas in VR, although you can position the viewer exactly where you want them to be in space, you cannot control where they look. The viewer decides. And this small difference fundamentally alters the storytelling paradigm.

For instance, there are no true close-ups or medium shots in VR. Unless the actors are deliberately blocked (or the *mise en scène* carefully arranged) to create the effect of a mid or close-up shot, most scenes play out as wide single-shot solutions. Even when faces or objects are thrust toward the camera,

viewers are free to look away at other parts of the frame. This is why traditional editing more or less breaks down in a VR film. The editor has no way of knowing where the viewer is looking, therefore it’s not possible to cut from wide to medium to close without risking a disruptive effect on the viewer. A close-up may not make sense – visually or narratively – if the pesky viewer has been attending to something else in the scene.

For these reasons, VR directors are often trying to coach the viewer where to look, using voiceover or sound design, or by creating subtle in-scene cues such as actors pointing and yelling “What the hell is that?” As I say, it’s early days for VR cinematic grammar...

VR is undoubtedly a strange new paradigm for writers, directors, DoPs and editors, but few are suggesting it’s going to replace old-fashioned cinema or flat-screen telly any time soon. Just as the moving image did not render photography obsolete, VR will simply take its place among the communication arts – a new-fangled addition to the many techniques of visual storytelling. The 360-degree field of view is a canvas of new possibilities that will take media practitioners as far as their courage and imagination allow.

Fact File

Steve Cholerton has been DoP, director, post-production supervisor and creative lead on several VR projects. He is currently story director for *Alive*, a government-funded R&D programme designed to develop new technical and storytelling tools for cinematic VR. *Alive* is a collaboration between Figment, the University of Surrey and the Foundry. Shooting on Nokia OZO and Google Jump cameras, as well as a light field camera array built by the University of Surrey (see pp. 76–79), shots are composited into CGI environments built in the Unity game engine. See more at: www.figmentproductions.co.uk Tel: 01483 829591

GTC Workshop

Shooting for virtual reality / 360°



The GTC is planning a full-day workshop on this intriguing technology within the next few months. With the emphasis on actually shooting for VR and 360° plus dealing with the workflows, this workshop will feature input from Steve Cholerton of Figment Productions and Ashley Meneely, the Guest Editor of this issue of Zerb, plus a presentation and demo (including hands-on) of the Nokia OZO camera kit from Video Europe.



The day will hopefully also include a contribution from the BBC on their explorations into the potential of virtual reality and 360°. **More details soon.**



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A new (virtual) reality – for Video Europe

Not afraid to take a chance on new technology, GTC sponsors Video Europe took the plunge a while back and invested in a Nokia OZO 360 system. Now in a position to offer a very streamlined setup for 360/virtual reality shoots, they are finding increasing demand for a wide range of applications for this new way of viewing the world.

Video Europe have been providing crew and equipment to the broadcast industry since the early 1970s. We have seen all kinds of technological developments in that time, such as the arrival of tapeless workflows and the leap to Ultra High Definition (UHD). Over the years, to succeed in this industry we have had to be prepared to take risks on new equipment and our recent foray into shooting for virtual reality (VR) has been just that – but it has been a risk worth taking.

With the release of Facebook's Oculus Rift and the Vive, VR has become a possibility in the households of those that can afford it. Now, with companies such as PlayStation offering similar hardware at a fraction of the cost, more people than ever can enjoy 360 3D video content and VR experiences.

Choosing which system to go with

When we began our VR journey at Video Europe, we extensively researched and tested the growing number of 360/VR rigs on the market and there were significant reasons why we eventually decided to go for Nokia's camera.

360 recording is not new but in the past it was incredibly laborious to stitch footage together and manage clips from the multiple cameras. The Nokia OZO, however, is a great tool that can save thousands in post. Nokia's proprietary software is able to output a single file resulting in an extremely streamlined workflow.

Another failure of previous 360 technologies was the lack of live monitoring available to the user. Film-makers were forced to rely on blind faith and wait until post-production

Testing the Nokia OZO on our new Skate Plate



Using the OZO with a car rig in an undisclosed but exciting location

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The OZO allows the director and crew to view their shots, adjust exposure and view stitch mark locations, all live.

stage performances. Some of our favourite and most unusual shoots have been filming theme-park experiences and work training tools, as well as documentaries on all sorts of topics.

In operation

On VR shoots Video Europe provides a preview, capture and data-wrangling station using high-end Mac Pros in conjunction with the Oculus Rift to play back footage or view a live stream via the headset and display.

Facebook and YouTube 360 live streaming demand is growing rapidly and our Live OZO carts can process the raw video signal from the camera and deliver high-quality real-time stereoscopic stitching and multicamera switching to give a greater sense of immersion at large-scale live events. OZO Live integrates directly into our OB trucks and fly-pack department to offer a full multicamera broadcast package anywhere in the world.

The 360/VR field is rapidly growing into a highly competitive market but there are very few companies offering this camera with such a streamlined setup. Video Europe was the first hire company to acquire the Nokia OZO and the only one able to offer the very lowest price in Europe whilst delivering an unparalleled level of service and experience.

And if this has whetted your appetite, we are looking forward to working in collaboration with the GTC to produce a training day on shooting for 360/VR which will give us an opportunity to discuss and demonstrate some of the lessons we have learned along the virtual way.

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before seeing what had been captured. The OZO allows the director and crew to view their shots, adjust exposure and view stitch mark locations, all live.

New views

From large-scale football matches to the Persian Gulf, and plenty in between, the creative possibilities offered by VR/360 have kept on surprising us. We have found that environments to which the general public rarely have access provide an immediate opportunity for this medium – such as behind-the-scenes videos from film and TV productions, or of music and

Fact File



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