SPHERICAL VIDEO: YOU HAVE [EVEN MORE] POWER!

David Rabkin, PhD
Director, Charles Hayden Planetarium
Museum of Science
1 Science Park
Boston, MA 02114-1099
drabkin@mos.org

Abstract: At the 2014 GLPA conference, I reported on work by the Museum of Science, Boston's Charles Hayden Planetarium to create low-cost, remarkably high-quality spherical video for use in the dome. The paper offered advice on how to get started, and encouraged others to take advantage of this useful emerging technology. This paper is an update, two years later, and shares some of our successes and lessons using spherical video in the production of the fulldome show *From Dream to Discovery: Inside* NASA. Also, it reports on several of our experiments, outlines recent developments in the field, and poses questions about how 360 video can best be used. This field is continues to develop at a rapid pace, and now is a great time for planetariums to experiment with 360 video to support their live presentations and fulldome production.

Introduction

In the Charles Hayden Planetarium at the Museum of Science, Boston, we are comfortable using spherical (or "360") video in our productions and as a tool for creating visuals for use in live programs, as well. Our first two shows, *Undiscovered Worlds: The Search Beyond our Sun* (2011) and *Moons: Worlds of Mystery* (2012) were entirely animated. But when we produced *From Dream to Discovery: Inside* NASA, the team decided to try live-action, spherical filming using an array of 10 GoPro cameras, whose footage was stitched into a spherical video. This decision was made possible by rapid advance in digital video camera technology, rigs for holding multiple cameras, and software for stitching multiple video streams.

At the 2014 GLPA conference, partway through production of *From Dream to Discovery*, I presented a paper titled "Spherical Video: You Have the Power" that discussed the then-current state of the art and technology of spherical video as well as my hopes for its use by my team.

The current paper summarizes key points from my earlier paper, outlines some recent successes using spherical video from my planetarium's work and several others', shares a few lessons, and highlights some of the key advances taking place in the field.

I argue that today, we all have even more "power" than in 2014, and that the techniques now available to so many of us are worthy of investigation by producers and educators.

The Promise of Fulldome Video

In 2013, there were indicators suggesting that spherical video could provide compelling experiences for audiences. The World Views Network had used high-resolution spherical still photographs very successfully in its live presentations, and many planetariums had used photographic panoramas. Sky-Skan's *Awesome Light* series of shows, used beautiful high-

resolution spherical time-lapse imagery created with an array of DSLR cameras. *Earthquake*, produced by the California Academy of Sciences, successfully used two different live-action techniques – HD video inserted into an animated model for the remainder of the fulldome scene and fulldome shots taken with a Red One 4k video camera using a fisheye lens.

Each of these examples created satisfying experiences for audiences. Yet none combined moderate cost and technical ease with high-enough quality fulldome video.

Spherical Video for All of Us

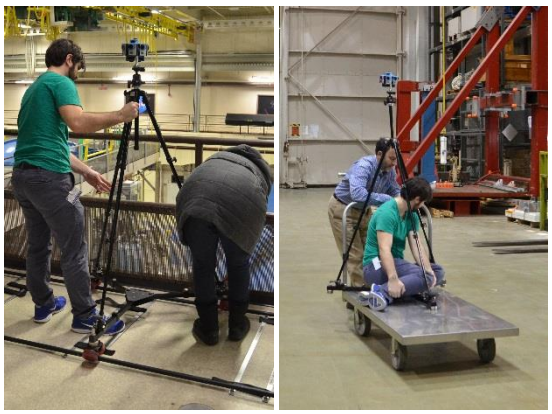
By late 2013, three critical pieces of technology had become available at moderate prices. The GoPro3 camera offered HD video in a very small, in expensive package. 360Heros manufactured (via 3-D printing) a compact, tripod-mountable rig to hold ten GoPros so their combined fields of view covered a complete sphere. And software from Kolor offered the ability to stitch and blend the ten GoPros' video streams into a single set of spherical master frames.

The combined price of our 10 GoPros, the 360Hero rig, the software and extra batteries and memory was about $5000, sufficiently low that now the chief barrier for many planetarians is know-how and time.

Successes, Lessons and Innovation

In 2014, I was able to share a few raw clips from the filming for *From Dream to Discovery* with the GLPA audience. Today, the completed show has received awards and been enjoyed by many thousands of planetarium visitors. Significantly, while an astute critic will observe limitations inherent in the GoPro cameras and small but noticeable stitching errors, these flaws do not detract significantly from the visitor's experience or distract from the story-telling. Our results compare favorably from a technical perspective with excellent shows from other producers using more expensive equipment and techniques. In short, using inexpensive equipment while also being sensitive to its limitations can lead to very compelling results, even for today's media-savvy audiences. As educators and story-tellers, we should not let comparisons to Hollywood or the quest for technical perfection drive out attempts to use good-but-not perfect technology in ways that will be satisfying and effective for audiences.

One challenge we faced in filming *From Dream to Discovery* was smooth camera moves. Any shake or unevenness in camera movement is amplified when projected on the dome; great care is required to prevent motion sickness among audience members. Of course, Hollywood has solved this problem with expensive equipment; the fullcome challenge also involves keeping equipment and people out of our shots, and doing so on a tight budget. We used carts on relatively short tracks and bare floor, crawling (so we stayed below the intended field of view) combined with great care (so the camera moved fluidly), and knee pads!



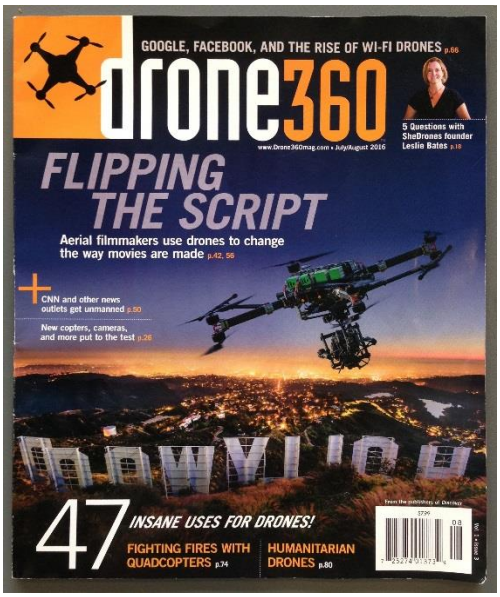
Low-cost track-based and trackless approaches

In the future, we'd like to experiment with the use of motors rather than people to move the camera smoothly. Others have

experimented with handheld gyroscopic camera mounts with some impressive results; these units, however, are pricey, and our preliminary experiments with cheap "steady-cam" substitutes have not been successful.

Software to stabilize images has been a boon for several years now, but no panacea. Each year, it becomes more effective, however, which lowers the threshold for minimum quality of physical camera control. In August of this year, Facebook announced a new and potentially breakthrough open source stabilization technology.

The hardware and software technology for using drones as a camera platform is evolving rapidly... so much so that I recently encountered a new publication – Drone 360 – while waiting in line at a… *supermarket!*



Now available… at your local supermarket!

The field of drones is complex and potentially quite expensive. But in addition to the extreme examples used by big-budget producers, there are far more humble technologies that combined with others (particularly software-based stabilization) and a mix of competence and respect for the technology's limitations, can offer affordable and satisfactory fulldome shots.

In the last year, my team has partnered with several professors and students at MIT on shooting coral reefs – underwater. It turns out that underwater shots make for great fulldome experiences when the cinematography is good. In our concentric theater with a horizontal spring-line, it's particularly compelling and realistic because there is no preferred direction. A beautiful coral could be found – or some big scary thing might suddenly appear –anywhere around you. We have used underwater shots successfully as the context for lectures delivered live in our planetarium.

Underwater rigs are available commercially for several kinds of cameras including GoPros. We found inconveniences accessing the cameras while installed in the rig, particularly when out on the water, and a lot of challenges relating to smooth camera moves. We also had some issues with heat dissipation, particularly for the hot-running GoPro Hero 4, in the plastic, and thus insulating, enclosures. With care and patience, these problems were largely addressed. A challenge for the future, however is lighting. Good results can be achieved in shallow water; but in deeper water, a combination of artificial lighting technology and better camera sensors will most likely be needed. One final challenge for under water spherical video is cost; under-water rigs add to the expense and so do all the peripheral costs associated with travel, boats, scuba equipment, etc.

While other producers have worked with extremely high-quality cameras (e.g., Mirage 3D and the California Academy's work using the Red One camera), we have begun experiments with some of the new and often-inexpensive cameras that are

introduced with remarkable frequency. Just under a year ago, Jason Fletcher, published a collection of new 360 camera rigs on his blog (go to www.TheFullDomeBlog.com, select the 360 Video category on the left, an scroll down), and the list continues to grow.

Recently, we in Boston started working with the Kodak PixPro SP360 4K, a $500 fisheye video camera (235 degrees total) using a sensor that is 2.8k-pixels across. It has provided remarkably sharp fulldome video for our 58' diameter dome. Further, stitching and parallax are minimized (two cameras are needed for a complete sphere) or eliminated (only one camera if you want a hemisphere or a bit more). This makes close-up shots a breeze. An internet search for "360 Leaf Cutter Ant Colony" will lead you to a great demonstration of the camera's capabilities via YouTube's 360 video viewer. This footage also looks excellent on our dome. By eliminating the complexities of stitching, this camera – and others, I'm sure – make it much easier to create and use 360 video. It's remarkable how good a sharp image on the dome sourced from a 2.8k master can be. And it won't be long before cameras in this price range can shoot at the native resolution of our 4k planetarium system.

Good Film-Making

Amid all the discussion of technological advance, it's critical to remember that story-telling and cinematography matter – and probably matter more than anything else. Even the best shows suffer from some deficiencies, whether it's stitching artifacts or lack of contrast. But when the story-telling is good and the shots are compelling, I and most audiences ignore the technical details and enjoy experiencing the story.

I'll offer no tips on great story-telling here other than a recommendation to work at it. But it's worth sharing a few thoughts on cinematography.

One of the great things about shooting a complete sphere is the flexibility it offers. Capturing more than the dome's typical 180 degrees is useful for two reasons. First, having the full 360 sphere gives one complete flexibility to shift the zenith in post-production. Second, it turns out that showing the audience some foreground is essential to creating a normal-feeling view in any terrestrial situation. A unidirectional tilted dome provides this naturally, but in any horizontal concentric dome, it's critical to compress more than 180 degrees of view – say 220 – onto the dome so the audience sees foreground. We have found that the audience ignores image distortion up to about 220 degrees of view on the dome. Beyond that, distortion is evident – except in unfamiliar contexts. For our under water shots, we've been able to use 240 degree fields. The same would likely prove true in upwards-oriented drone shots of landscapes. Spherical video, then offers the fulldome producer maximum flexibility for experimenting with and handling scenes.

It's worth noting that sharpness and contrast can, within reason, trump resolution. We found that a great shot at 2.8k is superior as an *experience* than an adequate shot at 4k.

Of course, the other rules of film-making still apply. Composition matters, and so do camera moves and transitions between shots. Differences in light across a fulldome shot can be difficult to address technically; so care must be used in planning and executing shots. There are countless dos and don'ts. But the most important DO is to get out there and try. There's no substitute for experience – planning, setting up, filming, processing and then seeing what works well on your dome. In a field that is so new,

undefined, and rapidly changing it's up to all of us to learn empirically, to share, and to inspire each other (as well as our audiences).

A Note on Virtual Reality

Recent developments in 360 video photography have been driven to a considerable extent by growing interest in virtual reality. This field is a huge boon to planetariums and fulldome producers in several respects. It helps drive technology forward and bring down costs. It offers the potential for secondary markets or at least new channels for marketing and supplementary content. The fact that YouTube and Facebook introduced 360 video viewers serves as evidence that 360 has become mainstream. My museum is using these delivery media as part of our marketing and as an integral component of our online relationship with our audience, which means that my team is able to provide support to the institution in a completely new way and raise its profile by doing work that is high-profile, creative and fun.

Conclusion

We are well on the way to realizing the promise of 360 video that I shared in 2014. Since then, there have been notable successes in fulldome production and in the creative use of this technology. The technology continues to advance – increasing quality and ease of use as well as reducing cost or increasing technical capability. 360 video is becoming embedded in daily life online in ways that offer new opportunities for us if we're willing to be creative.

While it takes technical knowledge and skill to implement a 360 video work flow, with a little support from the community and a little discipline, most planetarians can use 360 video to produce satisfying results.

We still face some of the same questions we had a few years ago: What makes for a really good fulldome shot and is it different for live-action and animation? What live-action and 360 video techniques best leverage the unique characteristics of a tilted unidirectional dome – or one with a horizontal spring line? What techniques work well for including people in shots? How might we use spherical video in presenter-led, interactive programming? Can we imagine new kinds of audience experiences, or even new kinds of shows, that might be compelling?

While there are certainly technical challenges and technical improvements to come, the most important progress in this new medium/technique will be creative. As a community of producers, we have been given the power. Now, how shall we use it?

Resources

While there are now many sources of information online, searching for "360 video fundamentals" on Jason Fletcher's Fulldome Blog (www.thefulldomeblog.com) is a good starting point. You can select the "360 Video" category on the left to see all related posts.

Underwater footage from Belize using a rig with six GoPro Hero 4 Black cameras: www.youtube.com/watch?v=If3LUJ-KiQA (or search on YouTube for museum of science reefs of belize 360 video)

Leaf-Cutter Ants shot with a single Kodak PixPro 360 4K Action camera: www.youtube.com/watch?v=JQ3H5-wCgFA (or search on YouTube for museum of science leaf cutter ant colony 360 video)

Recent technical note about Facebook's new technique for 360 video stabilization: https://code.facebook.com/posts/697469023742261/360-video-stabilization-a-new-algorithm-for-smoother-360-video-viewing/