IPS2008 Workshop

Digital Image Capture for the Planetarium:

A working pipeline for filling the dome with still and video imagery

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ABSTRACT:

Digital tools now available allow the planetarium content creator to capture imagery that previously required expensive equipment and a difficult processing pipeline. This workshop will compare the cameras and lens equipment that is now obtainable, describe a working pipeline using standard image processing applications, and provide creative guidelines for creating the most dramatic imagery. Imagery capture appropriate for use in traditional planetariums as all-sky images and in fulldome video equipped planetariums, including the small portables is now within reach of everyone. From Earthbound subjects to the International Space Station, we will cover the use of digital camera capture for still images and time-lapse video.

PRESENTERS:

Tom Casey is President and Creative Director for Home Run Pictures, an animation and special effects studio that for over 20 years has been creating visual content for planetariums. He is currently partnered with Rice University's Space Institute and the Houston Museum of Natural Science in the five year Immersive Earth Project funded by the NASA REASoN educational outreach to create content for fulldome planetarium shows. His studio also has provided content for educational science documentaries produced for the Discovery Channel, National Geographic and PBS Networks.

Carolyn Sumners is Vice President for Astronomy and Physics at the Houston Museum of Natural Science and a 38 year veteran of the planetarium profession. The Museum's Burke Baker Planetarium opened the first fulldome digital theater in the US and has led in the production of shows using digital image capture – including flying a fisheye still camera to the International Space Station.

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INTRODUCTION:

Until recently, capturing imagery for the all-sky or fulldome video environment of a planetarium required expensive camera rigs followed by a difficult processing pipeline. Now that the photography market has become a digital realm that has all changed. It is now possible to readily obtain and easily utilize equipment and software applications that deliver professional quality imagery at a somewhat reasonable cost.

The equipment is available, but finding a workable match-up of camera and lens to achieve a fulldome image can be frustrating. The photography market is not aware of our unique needs and is probably not seeing us as a market that would be profitable to the extent they desire, due to the limited number of facilities that would purchase equipment. But there are cameras and lenses available that suit our needs… you just need to know what to look for.

What is the problem?

What we need to accomplish our capture of fulldome imagery is a digital camera and lens that provides a circle image that has the proper spatial geometry for projection onto our domes. Digital cameras of a wide variety are plentiful. And a lens, typically called a "fisheye" lens, is appropriate to match up with those cameras for our purposes.

Unfortunately this "fisheye" is a specialty lens and there is not much demand for it in traditional photography. Few have been manufactured over the years and few are being produced today. Interesting is the fact that originally these lenses were called "full sky" lenses and were described as being primarily intended for the astronomy and meteorology sciences.

After obtaining a lens, the user is confronted with another issue. For technical reasons we will only cover briefly here, digital camera manufacturers design their cameras with a sensor that is not the same size as the traditional film camera frame. It was decided that a smaller sensor would technically achieve their purposes better. Thus most digital cameras today are not what we call "full-frame."

It is simpler to design a digital sensor to accurately read the light rays passing through the central part of a lens because the angle at which they are striking the sensor is closer to a perpendicular angle. A smaller sensor has the effect of increasing the focal length of a lens, i.e., a wide-angle view becomes more telescopic. Not a huge issue in a more normal view lens, but totally undesirable for a fisheye. For our use, we need the fisheye lens to project the entire circle of its view onto the sensor… a smaller than full-frame sensor crops off parts of the circle making the image unusable for our purposes.

So our problem is to find a camera with a sensor that matches up exactly to what a particular fisheye is seeing… the end result being a full circle representing the entire area of a planetarium dome. Taking the few possible fisheye lenses and mounting them on an appropriate digital camera body can, at times, end up being a challenge and some very radical and awkward adapter arrangements have been attempted. Our goal here is to find various practical match-ups that are portable and easy to use in the field.

There are two basic types of digital camera sensors we are interested in… a full frame sensor that is the same size as a typical film camera's film plane, and an APS size sensor which is smaller, but usually consistent across cameras we desire to use. Figure 1. compares sensor sizes for two camera brands, Nikon and Canon.

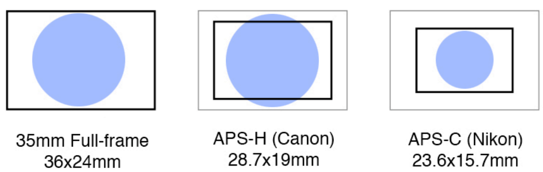

Figure 1.

The superimposed blue circle represents the image two varieties of fisheye lenses project onto the film plane. You can see that unless we match-up the proper lens with the proper sensor we will not see the entire circle that we need. Compounding this issue is the fact that a particular fisheye may only be available with a single mount type, thus making it impossible to use with a camera of a differing brand, unless an adapter is available.

There are two manufacturers that are or have been making fisheye lenses that we have found will work for our needs. Nikon has several lens models that it has made over the years… all now only available used. These Nikkor lenses project a circle that requires a full frame digital camera. The currently manufactured Nikon fisheye is not a full circle version and will not work for us. Obviously these lenses have Nikon mounts. Sigma currently makes fisheye lenses, one a full frame version, and also one that will work with the smaller APS sensor. Their lenses come in both Nikon and Canon mounts.

The camera bodies we have found most often to meet our needs for fulldome are Nikon and Canon. A discontinued professional camera from Kodak, the DCS/Pro also will meet our needs, and is usually fitted with a Nikon lens mount although a Canon mount was also made. These cameras come in various Megapixel sizes… 10Mp, 12Mp, 14Mp, or 21Mp and also feature either CCD or CMOS sensors.

Choosing between these various models first depends on which fisheye lens you can acquire, then on how many pixels are sufficient for your particular dome setup. Are more pixels better? Maybe less is sufficient. More pixels may be overkill for the size of your dome. Also, the newer sensors being designed for cameras tend to have better solved the noise problem in low light shots. Will you be shooting a lot of low light situations? This then may be an issue. There are no easy guidelines to make your decision simple… asking the opinion of someone who already has a camera/lens match-up or testing out the various match-ups yourself is the only way to know for sure.

Capturing and Processing

A very important decision when shooting will be exposure. Just like film cameras, digital cameras deliver their best images when the exposure is just right. Since we are dealing with a very wide field of view in a fisheye lens, the camera's through-the-lens metering may not be as accurate as needed… they are designed to interpret the views of more normal lenses. Some older fisheye lenses will not function at all with the camera's internal exposure meter and will need to be set manually.

A hand-held light meter with an "incidence" capability is an excellent way of getting the correct exposure. These meters have a tiny white semi-sphere that measures the light in the entire scene… kind of like a small dome, you could say. Although there are other manufacturers, Sekonic makes several excellent models of light meters with prices ranging from inexpensive to ridiculous. The Studio Deluxe is my favorite, it is compact, doesn't need batteries and is designed in the older analog style. The compact FlashMate and the fancier FlashMaster are good digital versions. Their other models cost more and have features the fulldome photographer will probably never need.

All professional-level digital cameras can save files in an image format called RAW. Although each camera make has its own version of RAW, it essentially is a file that saves all the information that the sensor saw during capture of an image. The lower-end cameras that only save in JPG format initially create a RAW file, but immediately convert that file to the JPG format. During this conversion, the camera's microprocessor makes all the decisions about exposure, color, contrast, detail, color temperature, etc. and you are stuck with what it determines… only limited changes can be made to this file after the image is saved.

Also, the JPG format is a compressed format, so you are losing some of what your camera originally saw for the sake of a smaller file size. Most fulldome processing pipelines are best served by an uncompressed format, as you do not want to lose any quality along the way to projecting your image on the dome.

Another advantage of RAW is that the format saves the image information across a 7-f/stop exposure range. This allows you a lot of flexibility, either in the assurance that a wrongly exposed image will still be usable or in other creative ways we will explain later in this paper when we discuss the processing pipeline. Simply, if your camera will shoot RAW… do it!

Your RAW images can be "converted" to a usable format in the standard image processing application called Adobe Photoshop through its RAW converter. Some camera manufacturers also provide an application for their particular version of RAW, but they usually do not have as many options available as found in Photoshop. Lightroom and Aperture are alternative applications to Photoshop, directed more at photographers and their processing pipelines. They also allow for many adjustment variables, are less expensive and may be sufficient for your needs.

The RAW interface comes up (Figure 2.) in Photoshop when you try to open a RAW file. There are several "tabs" leading to other pages that allow you to adjust many variables. You can change the color temperature and tint of the image, adjust the exposure across the captured seven f/stop range, correct for sharpness, brightness, contrast and saturation, etc… and all with much more range than if you had started with a JPG file.

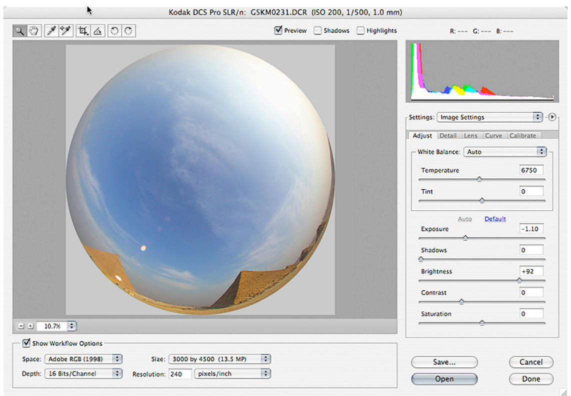

Figure 2.

The other tabs contain an almost endless amount of sliders to adjust everything you might ever need. Sliders are available to adjust things like level of detail, color noise, chromatic aberration, vignetting, etc. All these may sound overwhelming and unnecessary but when shooting with a fisheye lens (a very radical wide-angle lens) there are many details that you may desire to "fix" in your captured images before projecting on the dome.

Also, the RAW process is in a 16 bit format image, meaning it has 16 levels of color information instead of the typical 8 bit file we are accustomed to (280 trillion instead of 16 million colors). More color information to work with means less loss until you convert down to an 8 bit file for final use. There are also "color space" decisions that you can make in the RAW conversion depending on what processing pipeline or projection setup your fulldome system is accustomed to.

As you learn what works best on your dome, you will appreciate the options that the RAW path offers you. Fulldome projection systems are demanding in their needs. One area of demand presents a definite reason for giving yourself as much control as possible over the imagery you capture. Typical images that look good in other media will not project well on the dome. One reason is that a bright highlight area in our image will wash out the area on the opposite side of the dome. Being able to have more control over the intensities of shadow and highlight areas can help with this issue.

Furthermore, every dome setup is unique… different projectors, different graphic cards feeding those projectors and differing reflective qualities on the dome surface. Being able to control all aspects of your captures is a must to create good quality fulldome images.

In the Field

One of the most important things to do "religiously" is follow a back-up plan. Every image you capture is probably not easily repeatable, so losing your data due to a mistake is a hard lesson all of us want to avoid.

The flash cards digital cameras use to store images come in a variety of sizes and the sizes are getting larger all the time. Where once a 1 Gb card was considered huge, today there are 2, 4, 8, and 16 Gb versions with larger ones on the way. Although a larger card is tempting, remember that these cards are not perfect. Cards occasionally become corrupted and need reformatting. All your data on a corrupt card is lost. It is preferable to have several smaller size cards, so that if this happens your data loss is less. Even with an average amount of shooting, you will experience a corrupted card, so don't expect your cards to be your backup plan.

A laptop computer is a necessary tool out in the field along with a couple portable hard drives and a box of DVDs. Take your flash cards at regular times (every evening on a multi-day trip) and copy them to the portable hard drives and also to a DVD. Portable drives are extremely sturdy, but they will occasionally become corrupt so the DVD's are your final backup media.

Most of the higher-end cameras will allow you to operate them in what is called "tethered" mode… that is connected via USB or FireWire to your laptop. You can then control your tripod-mounted camera from the laptop and even have the images displayed on your screen and then saved directly on the computer's hard drive. It works great if you are shooting a time-lapse sequence. Figures 3. shows the screen view for the Kodak SLR/Pro's capture program, DCS Camera Manager.

All the options available in your camera's interface are also available in the tethered mode as shown in Figure 4. is another tabbed page in the DCS Camera Manager application. It is easy to setup and begin capturing a sequence of images this way. And being able to preview on your laptop's larger screen is a big plus. Also, being able to directly save to your computer's larger hard drive allows for longer sequences.

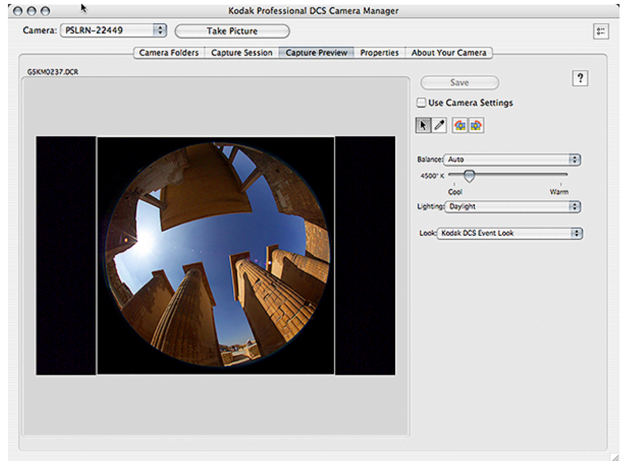

Figure 3.

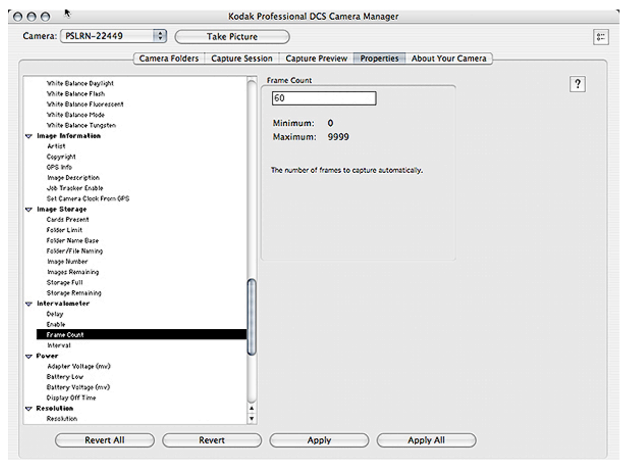

Figure 4.

There are several models of laptops that are designed for "rougher" treatment and if you plan on going to wet, dusty or high-altitude locations to capture imagery, consider getting one of these. We are shooting for planetarium programs, so traveling to desert environments simulating the surface of Mars, or to the top of Mauna Loa in Hawaii where the telescopes are is a possibility. Dust and moisture don't mix with computers and hard drives become less, shall we say, usable at higher altitudes.

My favorites are the Panasonic Toughbooks. Designed to "military specs," they solve all those potential issues you might run into in the field. There are several models to choose from, but they all are much more expensive than a typical Windows laptop. There also are a few stand-alone data storage devices being marketed. Essentially, these units are hard drives with a simple OS and usually a screen. They have slots for SD and CF cards built in and allow you to skip the use of a computer in the process of backing up to the hard drive in the unit. The ones with a large screen also are great for reviewing the day's collection of imagery. Epsom makes a couple models that are nice if you are going somewhere where a laptop is not convenient. There are lots of other manufacturers as well who make these units.

Experience

With the information here, you might expect to jump right in and begin capturing fulldome imagery, but remember, it will take some time before you are completely happy with the images you capture. There is a learning curve that will depend on the camera and lens you choose, the pipeline you follow to process the imagery and the dome projection system that displays the results.

Most of our experience has been gleaned during actual productions, like the NASA REASoN funded Immersive Earth projects. For "Dinosaur Prophecy," we traveled to locations where dinosaur fossils or tracks could be found and used the imagery to fill in the story between the CGI animation sequences where we brought the dinosaurs to life. For "Secrets of the Dead Sea Scrolls," almost the entire show was captured imagery.

At the Houston Museum of Natural Science, we have begun to send out fisheye equipped cameras with researchers or scientists traveling to distant locations. For these photographic novices, we have developed a successful training course – even when using a camera/lens combination that requires more difficult manual settings. Scenes for the HMNS produced fulldome shows, "Lucy's Cradle" and "Ice Worlds" were captured by researchers on their first fulldome photographic safaris.

Sending a fisheye/camera combination into orbit with the STS 120 astronauts proved to be most challenging. Because of certification issues, we were forced to use a traditional Nikon 35 mm film camera body with a Nikkor 8 mm fisheye lens… the resulting film being scanned to create our digital images. The film-scanning route has an effective limitation for the resolution of the final images.

In general, the ability to send a camera wherever the action is can be incredibly valuable, especially in building up a large library of good quality fulldome imagery.

Creative Considerations

Briefly, there are some creative guidelines that we can mention here that will help you capture better fulldome fisheye images. Some of these may seem obvious, but after using our cameras for several years now, we have learned that the obvious is not always what it seems when shooting through a fisheye lens for display on an immersive fulldome projection system.

First, it is surprising how many times, when handing a camera mounted with a fisheye lens to an inquisitive admirer, that the person pears through the viewfinder and with glee responds, “wow,” but all the while is holding the camera in the typical camera position… straight forward. With a fisheye lens to capture images for fulldome use, the proper position would be straight up, or close to straight up if your dome is tilted.

This is not immediately evident until you think about what you are capturing… an image that will be viewed on a dome creating the illusion of an immersive environment. When I use one of my cameras in a tourist location, I often catch a lot of people gazing up into the sky wondering what I am photographing with my strange looking camera.

When shooting time-lapse sequences, a tripod is obviously a must… the images must sequence through from a fixed camera view to further the illusion. But a tripod is also a good tool for a single shot as well. Since we are enlarging these images potentially up to maybe 60 feet across in a larger dome, any slight vibration can destroy the sharpness of the image. And any lack of sharpness is multiplied in the dome.

Scene composition must consider the final presentation in the dome. Since fisheye lenses are extreme wide angle lenses, they make everything look farther away. This does not make for a dramatic fulldome scene. Composing a shot so that there is something in the foreground, hopefully “looming” over our heads, will always create a more “dimensional” looking scene. Give the viewer something to convey the three-dimensional quality of the immersive display they are experiencing.

The imagery captured in the Shuttle and Space Station also necessitated a technique that can be used in a production to enhance your show. By “walking” through a smaller, tight environment while taking images, a tunneling effect, which works well on the dome, can be achieved. Also, if your image is of a high enough resolution, you can zoom into the image to create interesting movement. In-orbit photography also faced lighting challenges not found in outdoor images on Earth. Experiments with using a flash and bouncing the flash off of a white wall behind the camera were somewhat successful… remember that a flash unit has a much narrower light-spread than your fisheye lenses view.

Lastly, remember that this image will be displayed in a dome, where the projection of a bright area will wash out the area directly across, or end up flooding the entire planetarium with enough light that the immersive illusion is lost. The best images will have large dark areas in the composition, emphasizing the main focus point we want our audience to be looking towards.

CONCLUSION:

With the digital camera tools now available, quality image capture for use in fulldome productions is readily available to anyone willing to dive in and learn the processes necessary to fill the dome with exciting imagery.