
making360

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problems of shooting

problems of stitching

preface

"THE WELL.
the town may be changed,
but the well cannot be changed.
it neither decreases nor increases
they come and go and draw from the well

structures change, but the life of man with its needs remains
eternally the same—this cannot be changed. life is also inexhaustible.
it grows neither less nor more; it exists for one and for all...
the foundations of human nature are the same in everyone."

we know technology will evolve exponentially, softwares will update, hardware will become smaller, lighter, and more efficient. the chapters we have written thus far could be irrelevant as of yesterday. so please continually constantly self-develop with us.

we want this book to be a town well, a reservoir of resources we can all draw from!

introduction

by Jason Fletcher

Let no one say otherwise, shooting 360 video is difficult and intense! It's a medium that has completely unique challenges. And that is exciting for both the tech folk and the storytellers. But you'll need to understand the many hurdles so that you can soar. Knowing the specific details, inherent limitations, and potential problems will only help to inform how to successfully create immersion. And that is what this book aims to do!

We are going to throw a bunch of information at you. Yet it's really up to you to connect the dots and understand the optimal workflow for your specific camera rig. This isn't your typical DIY book. Really to become adept at 360 video, you will need to perform test shoots and run into problems yourself. The best way to learn and gain valuable experience is to fail! With that said, we will equip you with a comprehensive approach.

Big Picture Workflow

There are many details that we need to discuss. And so we are taking a brute force approach, organized into chapters. But in reality there are distinct steps in a typical 360 video shoot:

- EQUIP: choose your gear
- SETUP: camera settings, memory cards, pair remote
- PLAN: stabilization, safety zones, actor blocking
- SHOOT: recording, synchronization, lighting
- IMPORT: ingest, file management
- STITCH: dailies quickstitch, color matching, render tiff
- EDIT: rotoscoping, color grading, final render

problems of shooting

The Elements

"Welcome, O life! I go to encounter for the millionth time the reality of experience and to forge in the smithy of my soul the uncreated conscience of my race."

- James Joyce, A Portrait of the Artist as a Young Man

Problem:

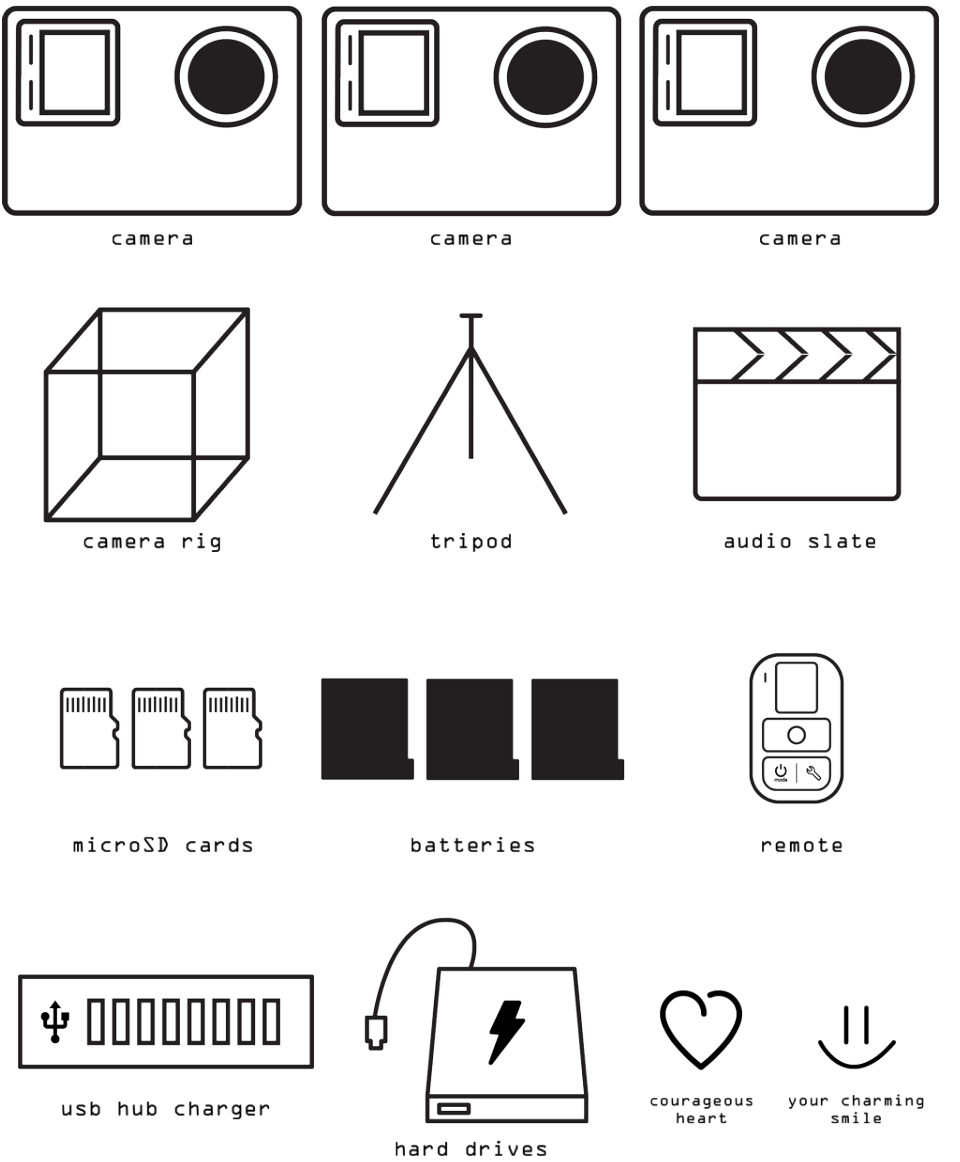
You want to be the next first greatest VR storyteller of all time and space.

You want to create audiovisual immersive experiences. You want to expand cinema, compassion, and consciousness. You want to explore change. You want to create new tools for self awareness. You want to help write a new cinematic language. You want to break open that window of limited views and climb out right into pure experience. You want to bring the world one step closer to putting ourselves in each other's shoes. Hello, astronaut! That's great but what are the first steps to take you closer? What materials do you need to shoot, learn, and grow right here right now today?

Solution:

Dive deep in. No fear. Take the first step. Then the one after that. Gather all the elements and start experimenting!

Here's a basic checklist for your journey:



have fun!

千里之行, 始於足下

"When we say expanded cinema we actually mean expanded consciousness. Expanded cinema does not mean computer films, video phosphors, atomic light, or spherical projections. Expanded cinema isn't a movie at all: like life it's a process of becoming, man's ongoing historical drive to manifest his consciousness outside of his mind, in front of his eyes."

- Gene Youngblood, Expanded Cinema

Platonic Rigs

"There is geometry in the humming of the strings, there is music in the spacing of the spheres."

- Pythagoras

Problem:

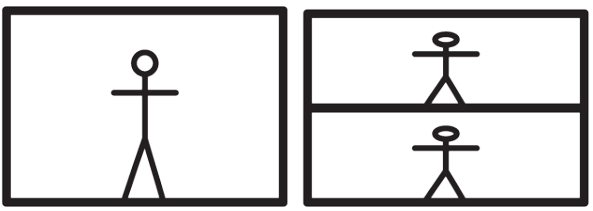
You need to choose a 360 camera rig from all the options and configurations available.

The popular 6 camera cube? 7 camera cylindrical layout? 10 camera layout? Or perhaps 3 cameras with modified fisheye lenses? Mono or stereo? What about spherical or cylindrical? One size does not fit all. Don't worry, we'll find the perfect fit. Selecting a rig depends on the type of content you are shooting, environment, distance, moving shots and of course money in the piggy bank.

Solution:

Prioritize your needs.

MONO vs STEREO



First decide between using a monoscopic or stereoscopic 360 video rig.

With a mono 360 rig, all of the cameras will together capture a single 360 video. No illusion of depth can be achieved. This is the simplier approach in every way.

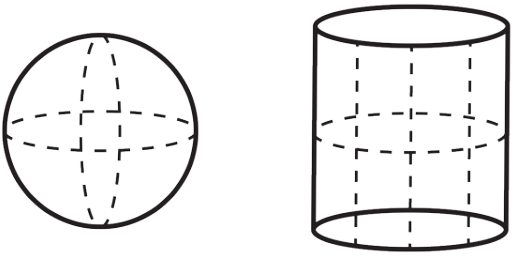
But a stereo 360 rig is specially designed to have cameras for the left and right eyes. Hence the need for double the amount of cameras. In this way 360 video can be achieved in 3D. But there are a few caveats...

In the end, it all comes down to overall cost. Stereo will give depth to the subjects and objects, enhancing the quality of experience but the costs will be significantly greater in both hardware and post production. If you have the budget and manpower, then stereo for the win! The difference is astounding and makes the experience more vivid and real.

If you are shooting on a tight budget look at the type of content you are shooting. Will the subjects and objects be close? If they are at farther distances or if you are shooting landscapes without close subjects, the stereo effect won't be as noticeable. You should save your money for a different aspect of the production. Another factor to keep in mind is how much control you have over the environment. If you are shooting a live event like a concert or sports then it will be difficult to control variables like subjects moving between seams of the cameras. The parallax and flaws between cameras is even more apparent especially for differences between stereo pairs. The errors will exponentially compound and cause viewing discomfort, eyestrain, and nausea. Shooting on set where you can control variables and block movement will be best for stereo. If you are sending a stereo rig into the field, be prepared for potentially heavy post production since environment variables will be out of your control.

With monoscopic videos you will be able to get higher resolution. To playback stereoscopic videos the left and right eye videos are stacked over/under and combined into one file resulting in half the resolution. If you don't have the budget for stereo, don't be too bummed as you can capture more detail over stereo with a 4K, 8K, and even 12K resolution out of your mono videos!

SPHERICAL vs CYLINDRICAL



If you have decided to stay mono, there are quite a range of options for you to choose from that offer high resolution. Again, pick the rig based on the style and type of content you are shooting. If you are shooting landscape with minimal subjects, then a cylindrical rig with more cameras around will offer extra high resolution. There will be more camera coverage around the horizon. However, because of the limited vertical FOV (field of view), there will be a hole at the nadir (floor) or zenith (sky). In other words, there will a zone where footage is not captured, but this may be okay because the viewer will not be looking at the sky or floor most of the time. So if you are shooting for a dome, the nadir hole won't be a problem since the camera rig will be on a tripod and won't be rendered into the fisheye shot.

The sky and floor can also be shot with an extra camera. You can even use a still camera, such as a Nikon or Canon. Then during the stitching process fix the missing zone and patch in the nadir hole or replace the tripod.

But a cylindrical rig is not ideal if you have multiple subjects moving around between cameras. More money, more problems. More cameras, more seams!

A spherical hemicube rig is an option if you have a smaller budget and less cameras on hand. There will be equal coverage between the cameras including the zenith and nadir.

FISHEYE vs WIDE-ANGLE

Another option for rigs is to modify the camera with a fisheye lens. You can achieve a greater FOV than wide angle lens and have more coverage per camera. In effect you will need less cameras for the rig, which allows the cameras to be closer together and have less parallax. An advantage of this rig is allowing subjects to get up close to the camera because there are less cameras and seam lines to break. It also allows for more footage overlap and can really help to hide any seams during the stitching process.

RECOMMENDED MODELS

MONO

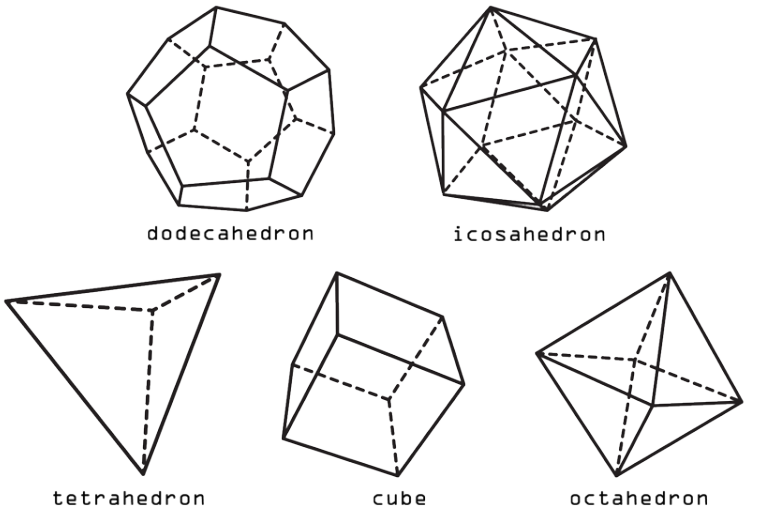
- 6 hemicube camera rig
- 10 camera rig
- 3 camera modified fisheye rig
- 4 camera modified fisheye rig

STEREO

- 12 camera rig
- 14 camera rig
- 6 camera modified fisheye rig
- 8 camera modified fisheye rig

For a comprehensive list of existing available solutions, see Jason Fletcher's collection of 360 video rigs on **The Fulldome Blog**.

MODELS OF THE UNIVERSE



Find the balance between the FACTORS
TIME...is money
MONEY...is power
DISTANCE...is time apart
DEPTH...is love
CONTROL. . . is an illusion
RESOLUTION...is a state of mind

Play Your Cards Right

Problem:

Which brand and size of microSD cards should you purchase?

Nike vs Adidas. FujiFilm vs Kodak. SanDisk vs Lexar.

Solution:

Sell out and go with the name brand GoPro endorsed and recommended cards.

Use the same make of memory cards for all the cameras. You want all the cameras as identical as possible so the microSD cards matter as well. Get the cards with the fastest read/write speeds. The cards with fastest write speed will perform better in the cameras. Also having the fastest read speed will minimize file transfer time. Spend more money on the higher class cards since they will last longer as well.

The SanDisk Extreme PLUS 64 GB or Lexar 633x 64 GB is recommended.

You need the cards with the fastest read/write speeds because when you shoot with a high resolution video mode on the GoPro cameras, then you are obviously dumping alot of data onto the memory card! So if you buy a knockoff memory card and the write speeds aren't up to snuff, then the camera buffer will fill up and will stop recording prematurely.

Formatting Cards

"N.Z: I suppose your explorations of new media are like swimming in an endless ocean.

N.J.Paik: A tabula rasa, you know a white paper. Video is a white paper, a tabula rasa."

Problem:

How do you keep track of all the cameras and tiny microSD cards?

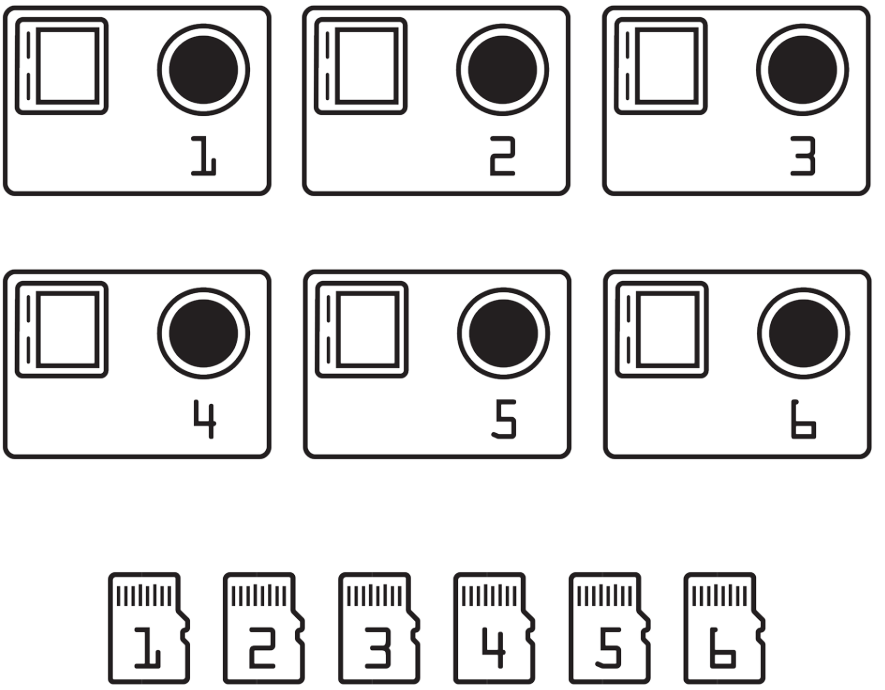
Be organized! Number your cards as well as cameras. Color code your cameras if you have multiple rigs. This will prevent headaches and confusion during textbfIngestion and post production. There are all the normal problems of shooting times x amount of cameras so proceed with extra care.

Solution:

Blank canvas and tweezers.

Before every shoot, format all your cards or file management will get really messy. Keep the same microSD card per camera so it is easier to troubleshoot. For example, if one card has corrupted files, footage that is out of focus, over exposure, or other problems you can track it down to the exact camera. Of course, always double check that your footage has been backed up before formatting.

Formatting the cards through the camera is best instead of on the computer so the original file structure and partitions are restored.



PROTIP: For the non-tiny hands, tweezers are very useful for getting the microSD cards in and out of the cameras especially when they are in the rigs and less accessible.

World Clock

Problem:

You need a system for file naming convention.

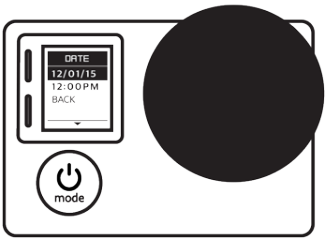
Camera 1 files start at GOPR0001.mp4, Camera 2 at GOPR1234.mp4, Camera 3 at GOPR4747.mp4 and so on.

Solution:

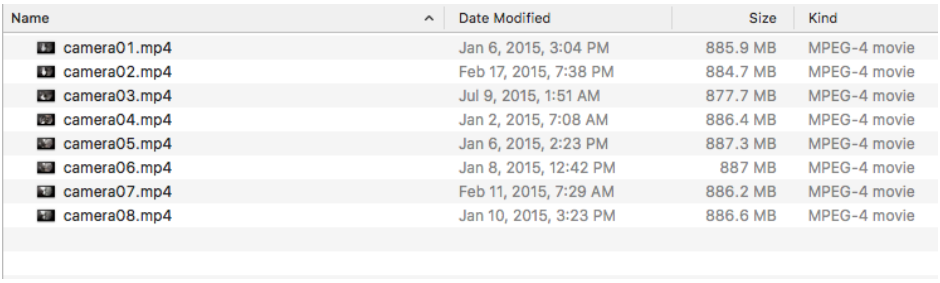
Use Time/Date for naming convention.

Synchronize the clocks for all cameras. This will make file management and comparing takes much easier later on. Inside each take folder you can check the details section and confirm that all the videos in that take start at the same time.

To set the Time/Date, use the menus on the GoPro or connect the camera to the GoPro app or software and you can manually set the clocks.

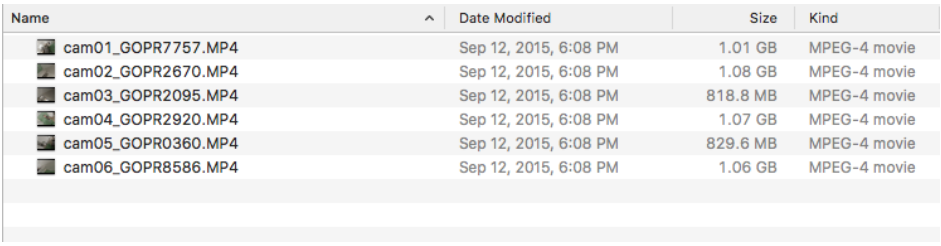


Here the clocks were not set. To confirm the videos are all from the same take, you can check the file size.



Name	Date Modified	Size	Kind
camera01.mp4	Jan 6, 2015, 3:04 PM	885.9 MB	MPEG-4 movie
camera02.mp4	Feb 17, 2015, 7:38 PM	884.7 MB	MPEG-4 movie
camera03.mp4	Jul 9, 2015, 1:51 AM	877.7 MB	MPEG-4 movie
camera04.mp4	Jan 2, 2015, 7:08 AM	886.4 MB	MPEG-4 movie
camera05.mp4	Jan 6, 2015, 2:23 PM	887.3 MB	MPEG-4 movie
camera06.mp4	Jan 8, 2015, 12:42 PM	887 MB	MPEG-4 movie
camera07.mp4	Feb 11, 2015, 7:29 AM	886.2 MB	MPEG-4 movie
camera08.mp4	Jan 10, 2015, 3:23 PM	886.6 MB	MPEG-4 movie

Here the clocks were set and much easier for the DIT or stitcher to organize the files.



Name	Date Modified	Size	Kind
cam01_GOPR7757.MP4	Sep 12, 2015, 6:08 PM	1.01 GB	MPEG-4 movie
cam02_GOPR2670.MP4	Sep 12, 2015, 6:08 PM	1.08 GB	MPEG-4 movie
cam03_GOPR2095.MP4	Sep 12, 2015, 6:08 PM	818.8 MB	MPEG-4 movie
cam04_GOPR2920.MP4	Sep 12, 2015, 6:08 PM	1.07 GB	MPEG-4 movie
cam05_GOPR0360.MP4	Sep 12, 2015, 6:08 PM	829.6 MB	MPEG-4 movie
cam06_GOPR8586.MP4	Sep 12, 2015, 6:08 PM	1.06 GB	MPEG-4 movie

For the month/day, you can use the day as the camera number and month if there are multiple rigs.

January 01 - camera 01, rig 1
January 02, camera 02, rig 1
February 04, camera 04, rig 2

The Time/Date can be used as a form of metadata for reference during the textbfIngestion and stitching process later on.

PROTIP: Every time you update the firmware for GoPros or if you leave the battery out for an extended time, the Time/Date will reset. Make sure to go back and synchronize the clock for all the cameras. Although you will be able to tell if the files are part of the same take from other details, like file size, it is easier to pull files across all cameras into a take folder from the same start time.

Set and Settings

"The nature of the experience depends almost entirely on set and setting. Set denotes the preparation of the individual, including his personality structure and his mood at the time. Setting is physical — the weather, the room's atmosphere; social — feelings of persons present towards one another; and cultural — prevailing views as to what is real. It is for this reason that manuals or guide-books are necessary. Their purpose is to enable a person to understand the new realities of the expanded consciousness, to serve as road maps for new interior territories which modern science has made accessible."

- Timothy Leary, The Psychedelic Experience: A Manual Based on the Tibetan Book of the Dead

Problem:

You have to set all the settings on the cameras.

You will have to set each camera manually by hand so decide the default settings you want to shoot on before changing them. Every camera must have all the same settings, especially frame rate!

Solution:

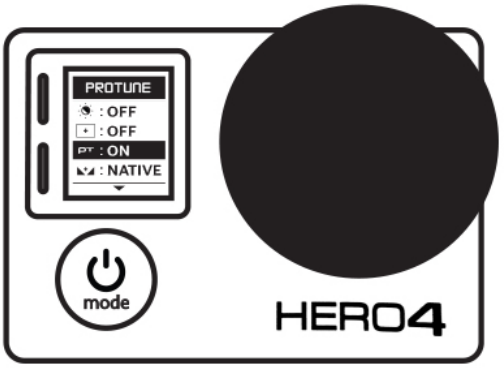
Keep it RAW. Match all the cameras. Find the sweet spot between resolution and frame rate.

You want your settings matched identically across all the cameras. This will allow them to stitch better and have less **Color Matching** and balance to correct in post. Start by deciding the frame rate and aspect ratio. This depends on the rig you selected. Certain rigs REQUIRE a 4:3 aspect ratio instead of 16:9 so there is enough overlap between all the cameras to

stitch. Be sure to check the recommended settings for the rig or do a test shoot confirming the settings provide enough overlaps.

If the cameras accidentally get knocked and the settings change it is ok as long as the frame rate and aspect ratio stayed the same. Even if one of the aspect ratios was different you *might* still be able to salvage the shot with some serious warping of that one camera. Or if the exposure is drastically different in some of the cameras you can do some color correcting at the stitching step. However, if one of the camera's frame rate changes you will be out of luck! There needs to be the same number of frames between cameras for the stitching software to apply a calibration to.

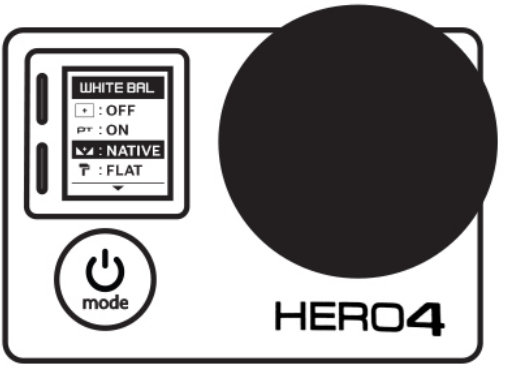
Protune - on



The protune setting should always be kept on. Protune will give you much higher dynamic image range and overall image quality with more detail in highlights and shadows. The image will shoot flatter for more freedom in color correction. Protune has higher data rate capture (up to 60 megabits per second) and less compression, giving you more information to work with (and less compression artifacts). Having a neutral color profile across all the cameras will give you more latitude and make it easier to color balance and correct for a nice stitch.

PROTIP: Turn protune ON first before you selecting other settings because the settings for resolution and FPS reset when protune is changed.

White Balance - cam raw



This keeps the color flat but you keep more information for color correcting and **Color Grading** during post production.

Resolution/FPS

Next decide your aspect ratio. Depending on which rig you are using, certain settings must be used for there to be enough overlap between the seams.

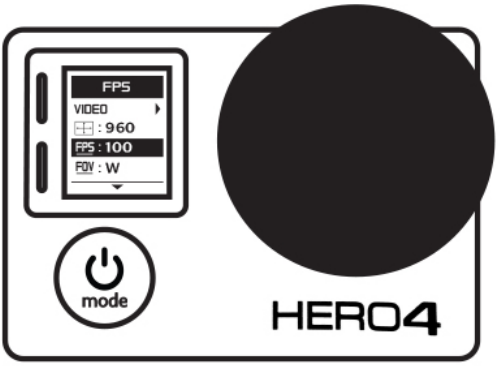
For a hemicube 6 camera rig like the Freedom360, 360 Heros Pro6, or 360Abyss the aspect ratio has to be 4:3 so there is enough overlap in the seams.

The most recent GoPro HERO 4's now offer:

2704x2028 at 30 FPS

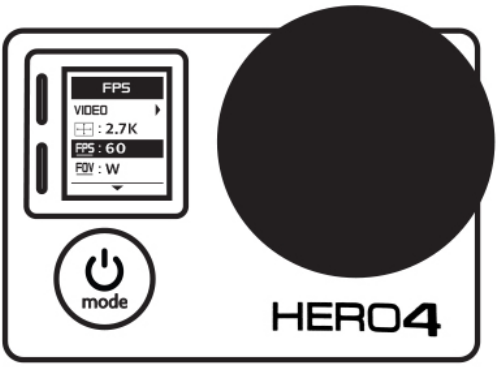
1440x1920 at 80 FPS

1280x960 at 100 FPS

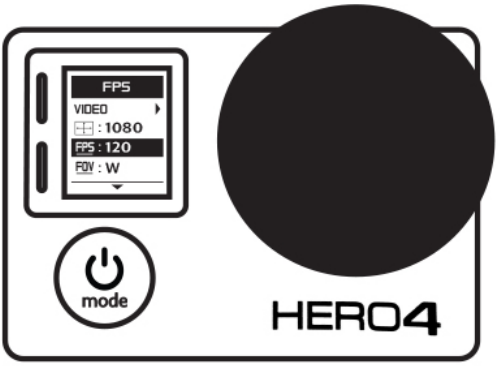


For cylindrical rigs, the aspect ratio can be 16:9 because each camera will be closer to the adjacent left/right camera. The 16:9 aspect ratio will offer enough overlap. Then you can use the 2.7K settings and have a higher resolution output stitch like 8K.

2704x1520 at 60 FPS

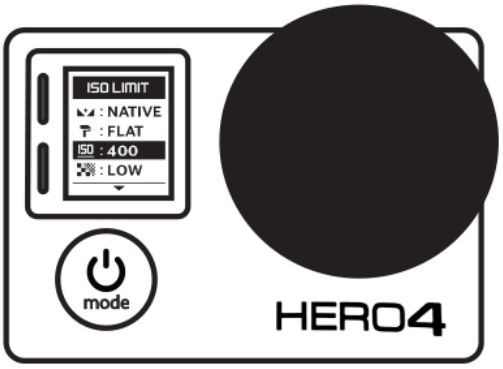


1920x1080 at 120 FPS



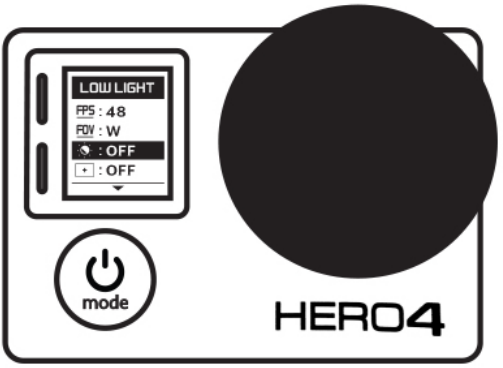
Choosing a higher frame rate will sacrifice resolution. Shoot at a higher FPS for fast high action scenarios like drone shots or underwater. Higher frame rate gives more frames to sync the cameras.

ISO limit - 400



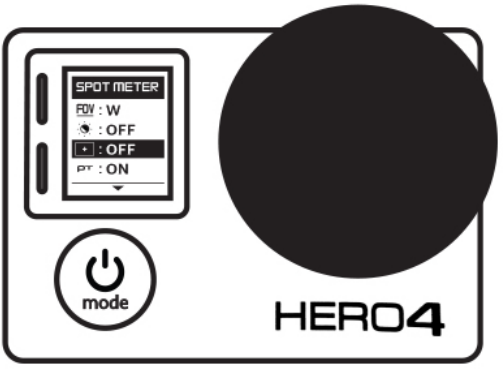
This adjusts the camera's sensitivity in low light conditions. Keep it at 400 which will give you darker videos but the least noise and gain.

Low Light - off

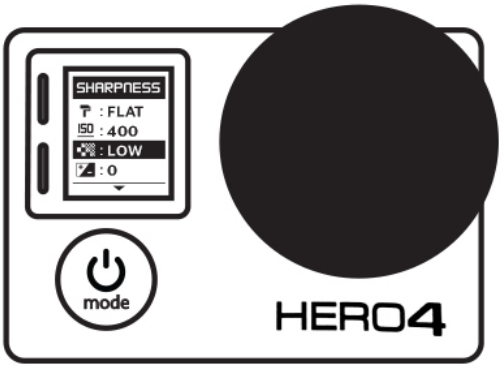


The camera will automatically adjust to changes in exposure when shooting in low light environments. Again, any setting where the cameras are automatically changing we want off so the cameras stay the closest settings to each other.

Spot Meter - off

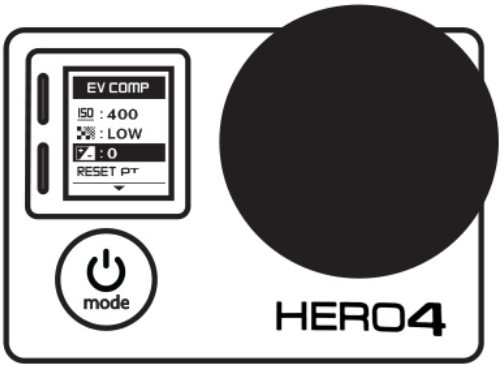


Sharpness - low



The videos will need to be sharpened during post production for more clarity and details in the headset. Use the low setting for less processing on the footage and more data in post.

Exposure compensation - 0.0



Range is -2 to +2, in 0.5 step increments. Leave the exposure on 0.0 and equal on all the cameras. If you have one or two cameras pointing at the sky, you can bump just those cameras up to +1.0 or +2.0. If you have a **Realtime Preview** or field monitor with you, try out different increments and adjust the settings accordingly.

PROTIP: When using a new rig for a shoot, test the cameras and adjust settings the day before! Unload the footage and do a test stitch to double check and make sure the settings are correct and best for that rig. If you are torn between higher FPS or resolution, do a test and check it out in the headset before. After you find the sweet spot, write down the settings and charge up the batteries for the shoot. Check again on the day of the shoot to make sure the settings did not accidentally get knocked in transit.

Get Juiced

Problem:

You charged the batteries last night but there's only one bar left all of a sudden!

Prepare extra provisions. GoPro batteries can drain very quickly so be sure to pack additional spare batteries. Over time they will also be able to hold less charge.

Solution:

Charge and recharge. Cycle and recycle.

You can charge the batteries inside the camera through USB or with external battery chargers. It's nice to have multiple dual battery chargers so you can speed up the process. Also, keeping a system in place to identify between drained or full batteries is helpful on set. Put gaffer's tape on the ones with full charge to identify between the ones that need to be recharged.

To lengthen the lifespan of your rechargeable batteries, use the batteries until they drain instead of constantly recharging them. Then they will be able to charge a full cycle and also last long with each turn.

PROTIP: Even when a GoPro camera is OFF, the WiFi can be ready and waiting. This is signified by the blinking blue LED light. But if the WiFi is left ON overnight, then the batteries will lose their charge within 24 hours.

Lifetime Supply

Problem:

You want to shoot a glorious long take or beautiful time lapse but the batteries might die halfway through.

With WiFi on, GoPro battery life lasts around 1:05-1:30 hours for the HERO4 Black depending on which settings you are on. If you are using the WiFi remote, then the battery will last 0:55-1:40 hours. Shooting a long take is not recommended for the faint of heart! The cameras may dip out from battery life, overheating or firmware issues. If you are up for the thrills, plan to at least be connected to a source.

Solution:

Connect to an external battery source through a mini USB cable.

If you are in an indoor situation then you can plug into the wall. If you are trekking through the wild west then bring an external power pack and lots of water. We recommend Anton Bauer battery packs.

PROTIP: The mini USB connector is extremely delicate so using a right angled cable might be gentler on the port. However, right angled cables have the tendency to break easily during travel but will be more convenient to replace than soldering back together the pieces of the camera connector.

Pair to Remote

Problem:

The camera rig is out of reach and you can't manually hit record.

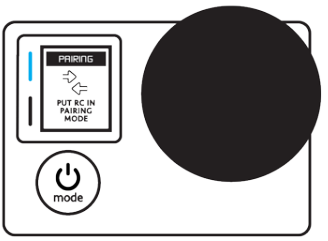
In some situations, you won't be able to manually trigger the cameras. For example, if the cameras are rigged high up, on a dolly or drone. You can use a WiFi or Smart remote to easily turn all the cameras in a rig on and off!

Solution:

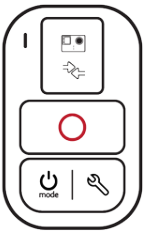
Use a WiFi or Smart remote.

The remotes can trigger up to 50 GoPros at once. Before the shoot, pair a remote to the rig. The WiFi will have to be turned on for each camera. This will drain the batteries faster so if you are in a situation where you can't use a **??** or constantly charge batteries and backups, then make sure to save power by turning the WiFi off between takes.

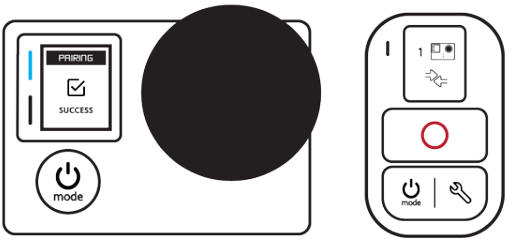
To pair a remote to your GoPro HERO4, turn the camera on and enter the wireless menu. Select "REM CTRL" and select "NEW" pairing. The camera will be in pairing mode for 3 minutes.



Next, turn the remote on and put it into pairing mode. If you have an older WiFi remote, hold down the red shutter button and press the white power button to turn the remote on and enter pairing mode. If you have a Smart remote, turn it on with the power and mode button. Once it shows a WiFi symbol, hold down the Settings/Tag button to enter pairing mode.



Both the camera and remote should now have two arrows pointing towards each other in the display. The remote will ask you if you want to pair another camera. Repeat until you have all your cameras connected.



You will probably want to use this method even if the camera is in reach so the cameras will roll at approximately the same time. The cameras will still be a few frames off from each other. If you are on set or have backup batteries then leaving WiFi on will not be an issue. If you are in the field and need to save all the power you can, stick to manually triggering the cameras.

Multiple Rigs

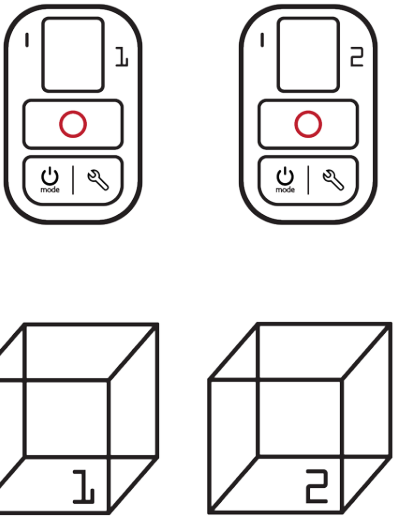
Problem:

You have multiple rigs in the scene and want to control them individually.

Solution:

Pair one WiFi or Smart remote per rig.

Pair the cameras to a remote and apply per rig. Remember to label or color code. Now you can control the different heads individually. Once the cameras in a rig are paired to a remote, they will stay paired to that specific remote. Label the remote that corresponds to each rig so they do not get mixed up.



Realtime Preview

Problem:

You can't see what you are shooting.

Happy accidents are sometimes welcome, in analog film they can result in beautiful emulsions. In VR, shooting blind is not the most ideal and can result in horrendous unfixable seams, dropped cameras, changed camera settings, etc.

Solution:

Create a realtime stitcher with TouchDesigner for live preview.

To create your own realtime preview, use **TouchDesigner's 360 Stitcher Component**. A powerful graphics card and video capture card is required. The Nvidia GTX 980 is recommended.

To stitch a 360 video, each individual camera is warped and then the edges of the overlapping images are blended to create a seamless panorama. For example, if you have 4 fisheye cameras, a fisheye to spherical conversion is applied to each camera. The 4 warped images are then edge blended together to form an equirectangular image. This same process applies for realtime stitching where the camera inputs are warped and blended together live. The equirectangular video is then mapped and textured onto a virtual sphere. The headtracking information from the HMD drives the rotation of a virtual camera inside the sphere. For an in depth read on fisheye warping, see Paul Bourke's blog post **Converting a fisheye image into a panoramic or perspective projection**.

The stitcher component will parse a PTGui Pro project file and create the amount of inputs needed and apply the warping. Similar to APG, take a

snapshot of a frame from each of the cameras and create a calibration. Then instead of applying the calibration to render video frames, the warping and position will be performed on the video inputs in realtime. Plug your cameras into the capture card through HDMI. Save your .pts file and load it into the stitcher component. Connect an Oculus Rift component in TouchDesigner to output the live feed to a headset.

Congrats! Now you have an on set preview for the director.

Sandbag

Problem:

You are using a monopod but can’t hold it without being in the shot.

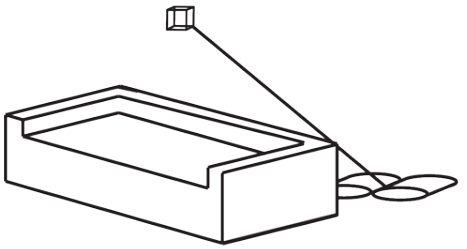
Unless you are taking the ultimate 360 selfie.

Solution:

Use a sandbag.

If you are shooting on set and have a controlled environment and props, you can use a monopod. Use parallax to your advantage and fix the camera rig so the monopod falls between two cameras.

For example, if you have the monopod diagonally set over a couch, then the sandbag will be hidden out of view. The monopod will fall into the parallax zone and not show up in the stitch.



Shoot the Moon

"when the sun is at its zenith, it must, according to the law of heaven, turn toward its setting, and at its nadir it rises toward a new dawn."

Problem:

You are using a tripod but don't want it in the shot.

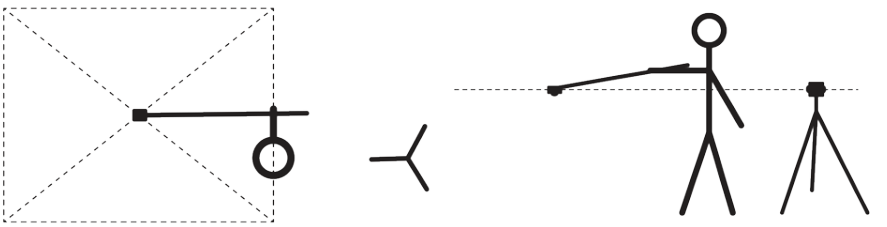
Sure you can patch in a logo to cover the tripod legs, but ads are lame.

Solution:

Shoot the nadir or zenith for replacement.

Bring an extra camera to shoot the floor for replacement later. If you are using a cylindrical rig, you can also capture the sky. The information can then be composited in post production.

Position the camera as close as possible to the nodal point of the 360 rig. If you have the camera on a pole then you can hold the camera out and have a partner move the camera rig while you shoot a still or 10 second video. Then place the rig back in the same position.



Hide and Seek!

Problem:

If the camera captures full 360 where do the director and crew go?

One of the challenges with VR is that it captures everything in the scene including the equipment, lighting and crew. You can hide some of the technology by dressing the set and camouflaging. Or you could write it into the story. The director could be an extra!

Solution:

Scope out a hiding spot.

Before shooting, plan your exit route and find a safe space completely hidden from the view of the camera. Make sure to hide your shadow self as well. With lighting, you can hide some of your lights in blind spots. Use a **Realtime Preview** or do a quickstitch test to check if the equipment is not in the shot.

Hit and Run!

Problem:

The WiFi or Smart remote loses signal with some of the cameras when you are out of range.

At the end of a take, when you come out of hiding to stop roll on all the cameras, the remote loses connection with some of the cameras.

Solution:

Leave the remote at the scene.

Instead of waiting for the WiFi to reconnect with all the cameras, wasting time and battery power, leave the remote with the camera after starting the shot. If shooting with a tripod, you can hide the remote under the camera in the blind spot. After the coast is clear and the take is complete you can come back to the camera and hit the remote which will still be connected to all the cameras.

Flashing Lights

Problem:

How do you know if all the cameras are rolling?

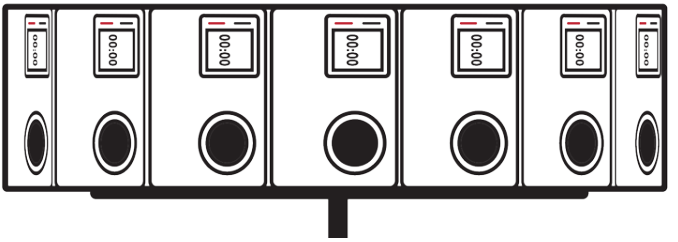
Look and listen for the signs and signals.

Solution:

Look for the flashing red firefly lights.

You can tell if all the cameras were triggered after you start each take by checking the red LED status indicator lights. They will continue to flash while they are recording so you can tell if a camera failed or cuts out.

Double triple check the settings on all the cameras before shooting and in between takes. The cameras sometimes change settings when knocked. There is a lot happening on set or on the road and things get out of sync. If an LED is broken, you can check the LCD monitor on the cameras. The cameras will show the runtime on the take when they are rolling.



Beep Code

Problem:

The GoPros beeping constantly are driving you insane.

kick
snare
clap
hi hat
beep

Solution:

Welcome the beeps. Or turn them off.

The constant beeping can be quite maddening whenever you are adjusting the default settings on all the cameras. Instead, reprogram your brain to receive positive feedback that the cameras are working. Use the beeps as sound indicators, that a take has begun or a camera has stopped rolling. Then the beeps only drive everyone else crazy and you will have perfect memory pitch of 659 Hz, which is an E5.

Frozen

Problem:

The camera keeps freezing up!

The camera froze halfway through recording and the LCD monitor is stuck. Pressing buttons does nothing. Is the camera dead? Is all the footage lost?!

Solution:

Remove the battery or change the microSD card.

Don't worry, your previous footage will still be there. The take the camera got stuck on may or may not have recorded up to the moment it failed. However, all your previous takes should be uncorrupted. GoPros will get stuck due to software issues or the microSD card.

First try turning the camera off by holding down the MODE button for 10 seconds. If this doesn't work, then take the battery out and put it back in. If that doesn't solve it, then make sure the camera is OFF and take the microSD card out to see determine if it is a software or card issue. If the microSD card doesn't have the proper write speed then it might not be able to keep up with recording.

On Fire

Problem:

The cameras are overheating!

When recording in high performance mode, the cameras start heating up, using up more power and possibly shutting down.

Solution:

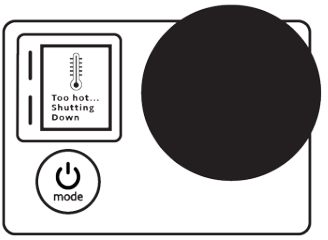
Keep it cool. Chill between long takes.

The HERO4 Black features unique high-performance video modes:

4K30/24 4K24 SuperView
2.7K48/50 2.7K30 SuperView, 2.7K 4:3
1440p80
1080p120/90
960p120
720p120

The cameras naturally consume more power to run these modes and will increase in temperature. When shooting 360 video, you will most likely be using one of these modes so give the cameras a break and have backup cameras if you can. The 360 rigs pack multiple cameras into a tight formation and the cameras generate even more heat next to each other.

When the camera overheats you will get an indicator that it is shutting down.



Give the camera some time to cool down and let it rest. It is not recommended to shoot on high performance mode for an extended period of time and duration. For long takes you will risk both overheating and power drainage. Again, have the cameras plugged into a **??** external source if attempting super long takes.

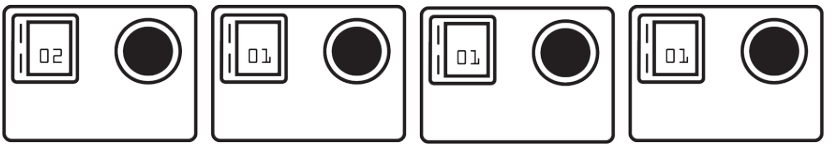
PROTIP: Add a tiny heatsink in the area between the lens and the power button. Heat can be a serious issue, especially if you are recording using the 4K video mode.

Misfires

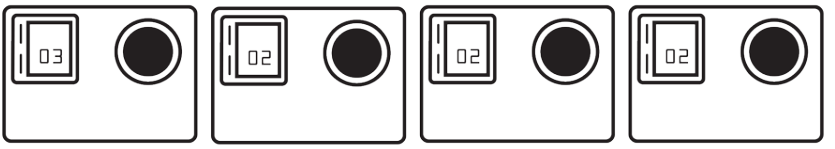
Problem:

Oops! You hit record on one of the cameras by accident.

It's easy to trigger one or two of the cameras and multiple times throughout the shoot. This offsets the camera take numbers from each other and makes it a headache during **Ingestion**. For example, after take 01 you triggered camera 1 by accident. After the next take, camera 1 will be at 03 files but the rest of the cameras will say 02. If you triggered different cameras more than once, things start getting more confusing!



take 01

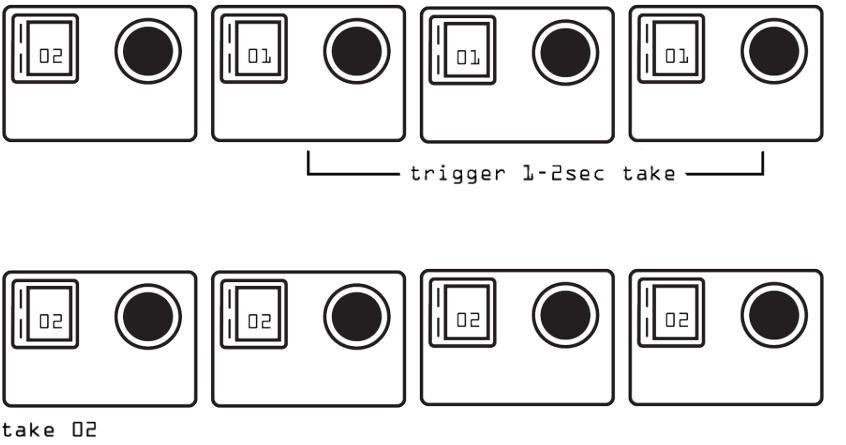


take 02 -camera 1 offset

Solution:

Play catchup.

If you trigger an individual camera, check the count number on all the other cameras. Then trigger those cameras for 1-2 seconds to increase the take count number. For example, if you misfired camera 01, then trigger cameras 02-06 to match the same amount of takes as camera 01 and all around. If you misfired a camera twice, then apply the same method. During the ingest, the takes will then match across all the cameras and be easier to separate into take folders.



Ring Around the Rosey

Problem:

The remote is out of battery or you need to save camera battery and keep WiFi turned off.

If you are shooting all day in the wilderness and can only pack so many backup batteries, then leave the WiFi off on all the cameras. This will save power however you will not be able to control them with a WiFi remote.

Solution:

Manually trigger the cameras.

Turn the cameras on and hit record one by one. Duck duck goose! Double check that all the cameras are rolling. If you left the sound indicators on you will hear a beep for each camera you turn on and also check that all the LEDs are blinking red.

Reference Signals

Problem:

You need to synchronize the cameras to each other.

There is no genlock sync on the cameras yet so videos will have to be synced manually in post. Give yourself or the stitcher as many ways possible to find a sync point.

Solution:

Audio Slate

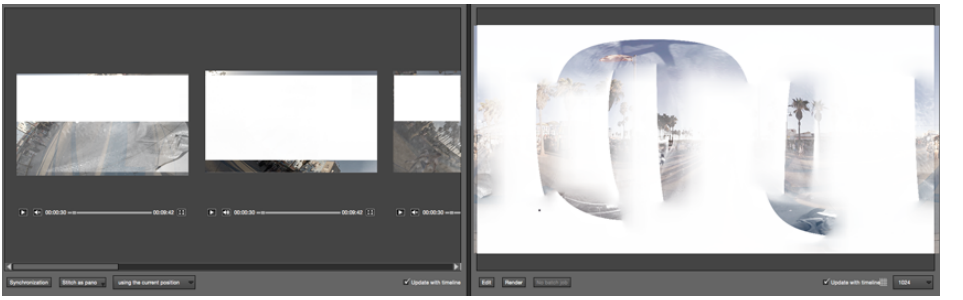
The old fashioned slate. 3 loud claps of your hands. Or any noise with a fast sharp attack will be easier to sync in post.

Motion Flash

If you have the time and materials, do a motion flash sync in addition to audio. The speed of light is faster than sound so a flash sync will be 900,000 times more accurate than audio sync.

Some people like to twist the camera rig for motion detection but this shakes the individual cameras in the custom rigs and is not accurate down to the exact frame. Use an umbrella over the rig and give it a flash with a speedlight. In post, you can find the exact moment where the white from the flash emerges, down to the exact frames.

Here is a test with a speedlight at 60 FPS.



Even at a high FPS, you can see that the cameras are still fractions out of sync from each other. This is a problem until there is true genlock/frame sync. Notice the GoPro rolling shutter effect.

DIY Genlock

MewPro is currently working on a genlock dongle that will allow true genlock syncing for multiple GoPros. The dongle allows frame sync (VSYNC) as well as scan line sync (HSYNC) but are only available for the Hero 3+ Black currently. MewPro Genlock Dongle uses Arduino Pro Mini 328 3.3V 8MHz.

Learn more about the **MewPro Genlock Dongle by Orangkucing Lab.**

Safety Zones

And where do you place the viewer in all this?

"As someone seated on the bank of the gushing torrent, taking in everything that flows past, the flurries of motion and the moments of calm. But I hope also as someone who plunges into the current, literally bathes in it, carried away by the flight of their own imagination."

- Hou Hsiao Hsien, Interview on THE ASSASSIN

Problem:

You don't want seam lines, ghosts or broken limbs.

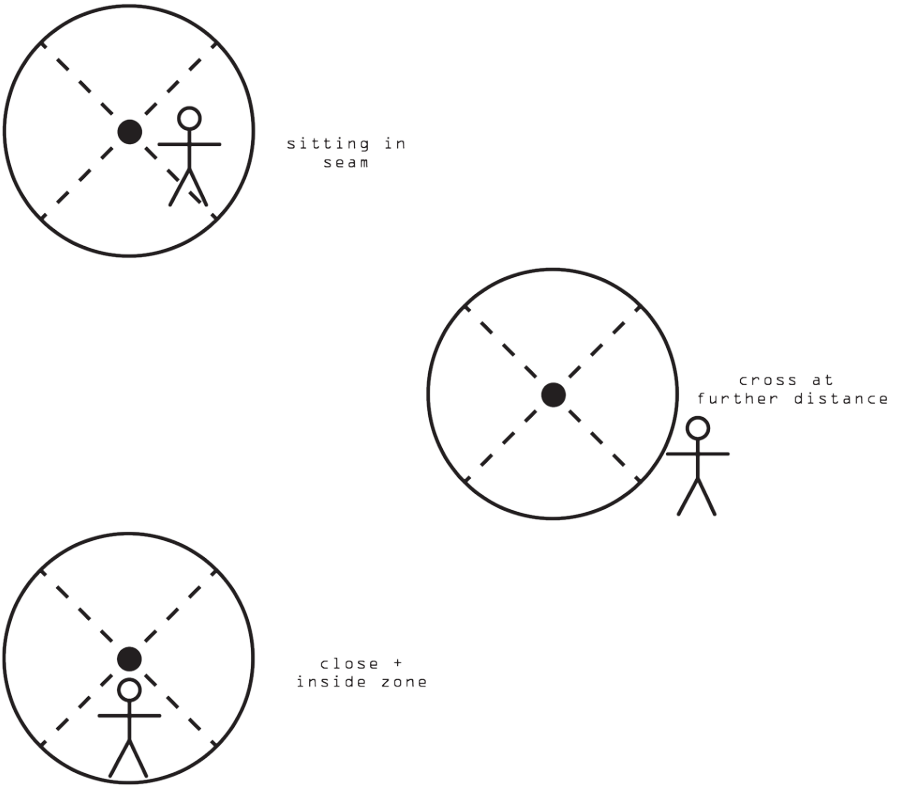
If you don't want siamese twins, meaning weird errors during the stitching process, then keep subjects out of the hazardous seamline zone. This will save frustration and hours of keyframing, **Rotoscoping**, using **Masking Markers** and render time during post.

Think like a stage director or magician and block actors for the space.

Solution:

Block subjects to stay within boundaries.

Have the subjects stay in fixed areas within a camera. If they must move between cameras, have them cross a seam line at a further distance from the rig so they are smaller. The seam will then be less noticeable. Tape, mark down, and rehearse. Remember to remove the guidelines before shooting or they will be in the shot! If you have a **Realtime Preview** or field monitor, check to see if subjects are sitting in or crossing a seamline.



If you are in the field and have no control over the environment, then adjust and turn the camera rig for the least seams on the main subject and action areas. In VR, you are not chasing a shot, but setting up the rig and letting the moment flow to you. Follow your intuition and place the rig in a good position. While you can't frame the shot, you can think spherically and compose the space.

Clean plates.

If you are shooting a scene where subjects must cross seamlines, record a take of just the environment. This will give you a clean plate of the background for **Rotoscoping** and stitching with the **Background vs Foreground** approach.

Stabilization

Problem:

You are shooting a moving shot and need to have the smoothest stabilization.

The easiest type of 360 video shots are static, with the rig placed in a fixed position. But adding smooth camera movement can add a great sense of immersion to a shot. After all, as humans we are always moving and it's what we expect when watching media, otherwise it can feel a bit dull. Dolly and drone shots add exciting movement to the experience. However, extreme care and caution in stabilizing the shot is needed or the viewer may get instant motion sickness. Any movement of the camera is magnified in a VR headset and can cause nausea if not shot properly.

Solution:

The biggest thing to keep in mind is the inherent limitations of your specific rig. This isn't a typical camera... so using it requires a different frame of mind. Indeed, not only does the technology have many hurdles but also the process of shooting a moving shot!

While recording the shot if any actors or objects get too close to the rig, on average 6 feet, then the parallax seams are going to be very obivious upon stitching. These seams completely ruin immersion because it suddenly exposes the magic. Create an imaginary boundary line in your mind and your shots will be beautiful and your stitching easier.

Each rig is different and you'll have to experiment to understand its particular limits of where the parallax is too obvious. Such as for rigs which use fisheye lenses, they have a huge amount of footage overlap so you can get closer to the rig.

Prior to the 360 shoot, think through the camera movements in-depth. Make sure that everyone involved in the shoot understands where the imaginary boundary line is and why they shouldn't get too close to the rig.

A few crazy but surprisingly effective solutions

Most solutions for obtaining a super smooth camera motion will mean that the dolly, drone, or vehicle will be within the shot. So get creative and figure it out! Here are a few tried and true approaches:

3-axis Gyroscope
On one end of a monopod stick is your 360 rig, and on the other end is the gyroscope. There is a sweet spot on the monopod stick where you can hold it and the 360 rig will remain high up and level, but the gyro will keep the shot extremely smooth. It is an odd sensation to walk around with it since gyros can act strangely when you turn certain directions, but that's just part of the technique. But there are restrictions in its use. They are heavy, weighing between 2-5kg (4-10lbs) including the bulky but necessary battery. Also, they take about 8-10 minutes to spin up and then their run time is limited. The Kenyon Gyro Stabilizers are pretty incredible.

Tracked Dolly
Lay down some rail road tracks and then put your tripod onto it. Then you can crawl on the ground and push your rig along very slowly. Or you can use some rope and pull it slowly from a distance. But yes, the dolly tracks will be in the shot; perhaps you can find a way to hide them? The Singleman Indie-Dolly is surprisingly affordable and is very portable.

Drone UAV
This can be tricky since the drone needs to be able to lift the weight of the 360 camera rig, but there are options out there. The **360Heros: 360 Orb** is a drone which in effect is invisible.

Fishing Line
Grab some high gauge fishing line and string it between two points high up in the air, while making sure one point is slightly lower. This will ensure

that the 360 rig will slide down the incline. Be sure to first test it out with some object that matches the weight of your 360 rig... The last thing you want is for your 360 rig to come crashing down!

Manual / Motorized Wheelchair
A manual wheelchair can provide a surprisingly smooth shot. The tricky thing here is to make sure that you are pushing the wheelchair evenly forward. It's easy to accidentally get some shimmy motion, since its difficult to make it just move perfectly forward. But this is obviously not a problem with a motorized wheelchair.

Car, Golf Cart, Airplane
Use powerful suction cups to mount the 360 rig to anywhere. Cinetics makes a wonderful mount called the CineSquid to do just this.

Lighting

Problem:

You want the most optimal lighting conditions for the shoot.

Lighting is tricky with the GoPros. With low lighting conditions, the image has a lot of noise. Too much artificial lighting causes a variety of problems such as a blown out image, pollution, and color variation. Lens flares are also more common with wide angle and fisheye lens. If shooting in stereo, the flares and differences cause a jarring image. Also, where do you hide the lights??

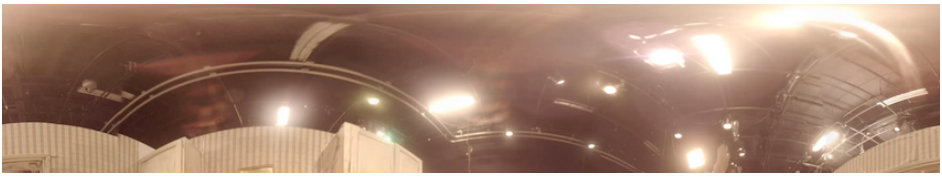
Solution:

Stay natural.

When shooting outdoors, if you have the time and patience, wait for the right moment. Try to shoot around dusk when the sun has just set but still emits a light hue. However, there is a small window to catch the perfect timing. If shooting at a different time of day, the sun will be pointing directly into one of the cameras, causing overexposure. You can **Shoot the Moon** and try **Patching Nadir** if it is the camera pointing towards the sky.

For interior shots, do not use too many different artificial lights. They will cause various colors and shadows. Unless you are shooting a J.J. Abrams style VR piece, be careful with pointing light sources directly at the lens, creating lens flares.

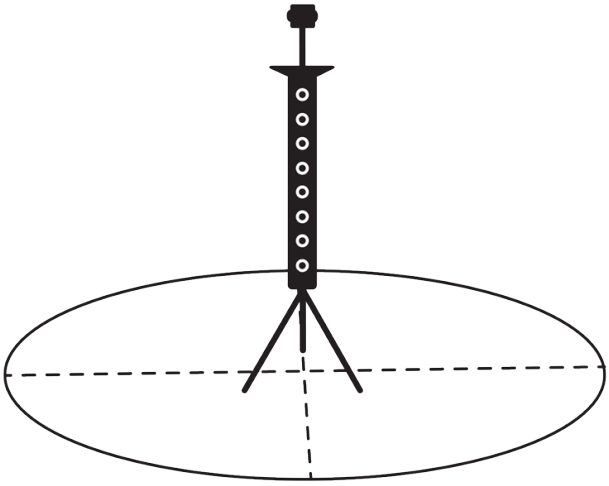
Be careful not to use too much tungsten lighting or the infrared pollution will cause a purplish hue and need to be color corrected.



Everything will show in a 360 shot and unfortunately you cannot play hide and seek with lights. Try dressing your set and hiding light sources in blind spots.

Get the LEDs out.

A simple option to add just that little bit of extra light to an interior, night time, or underwater scene is to clip a few compact but high powered LED lights onto the tripod underneath the camera rig.

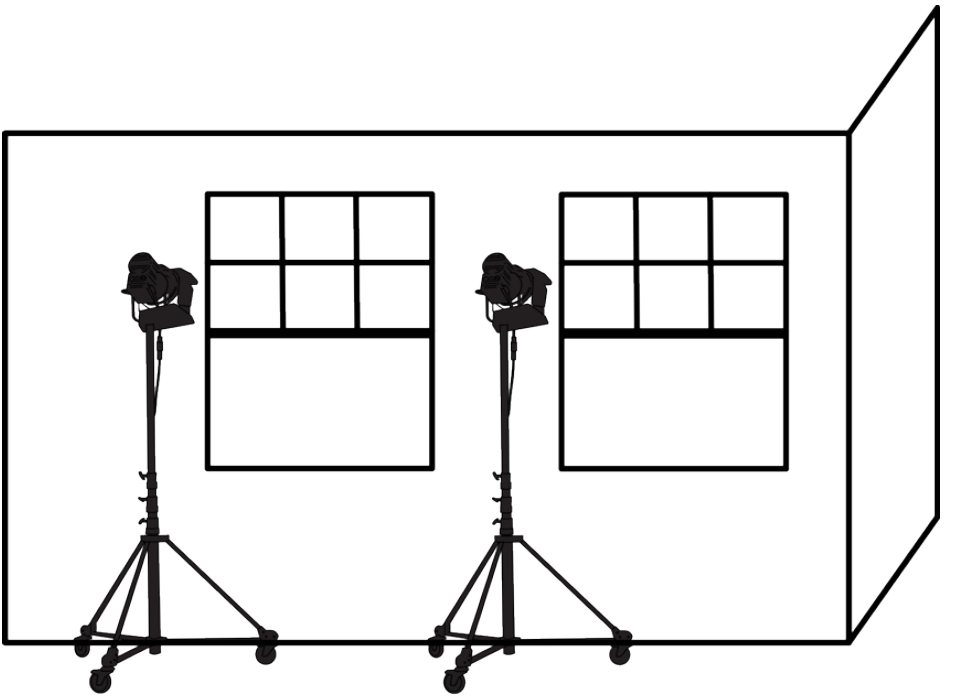


If you go with this lighting option, you should take a moment on set while filming to review the imagery coming off the downwards facing cameras to ensure they aren't catching any lens flares from the LEDs. If you are getting flares then you might need to mount a small flag to cut down on the unwanted stray light.

Get some outside help.

If you are filming on location at a physical structure like a house, a low rise building, or a church, you have a nice option for adding some extra light to your interior 360 shots without having to do the usual post production and roto cleanup work to hide the light fixtures that would be visible if they were placed inside the actual room you are filming.

You can do this by renting a few large HMI lights from a grip and camera supply company. If you place the HMI light fixtures outside the structure you can beam more light into your interior shots through the windows. HMI lights have a nice property where they give a very clean and high output illumination that closely matches the natural color temperature of daylight.



One thing to keep in mind is that since HMI lights use a metal halide gas, have a very high power demand like 12 kilowatts / 18 kilowatts / or 24 kilowatts that typically require a generator, and get hot quickly, you need to make sure to get some help from a professional lighting crew person

when moving and setting up the lighting gear so you don't have issues or lose valuable time during a shoot.

Also keep the HMI lights set back a distance from any wooden siding or flammable objects on the location as the lights and objects nearby can get warm if the lights are left on for a few hours. Also, when renting gear, it is good to know that using a modern HMI light fixture is much better than renting an older model as the new HMI light controllers can hot restrike the arc on the HMI gas so you don't have as much down time between turning the lights on and off.

Popular HMI lights for on location lighting use are the ARRI **ARRISUN**, or Mole Richardson's **Daylite Fresnels**.

Modified Fisheye

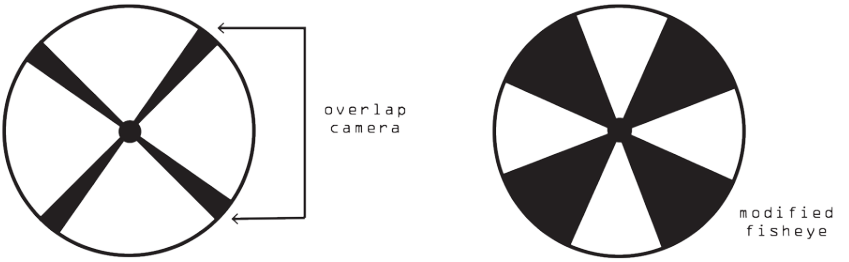
Problem:

You want to shoot with fisheye lens.

Solution:

Carefully remove and replace the lens.

With modified fisheye lens on the GoPros, you have greater coverage per camera with more overlap. Less cameras are needed in the rig for a full 360 stitch which means less seams and parallax! Subjects can get real close to a camera without breaking a seam. With more overlap, you can also shift the seams when rotoscoping or masking. However, since there is so much more coverage, a lot of the image is in the overlap, resulting in a lower final output resolution for the panorama. Shoot on the 2.7K settings to achieve 4k final output.



Step one. Prepare your tools. Removing a GoPro lens is a very meticulous process and you surely don't want to have to tear it out. Here are the tools you need.

GoPro HERO3 or 4, Lens, Lenscollar, Flat screwdriver, Mighty wrench

Step two. Remove the battery and SD card.

Step three. Remove the lens' outer ring using the screwdriver from the three different positions. You will be breaking the glue points, pulling out the outer ring gently.

Step four, the most critical step. Remove the lens. The lens has to be unscrewed from the GoPro lens mount. Use the mighty wrench to hold the lens strongly while rotating the GoPro body counter-clockwise. Keep rotating it until you are able to unscrew the lens with your fingers. Use the heat gun again if needed instead of forcing it.

PROTIP: Since the original lens is also glued from the inside of the lens mount, use the heat gun for 5-10 seconds over and around the lens.

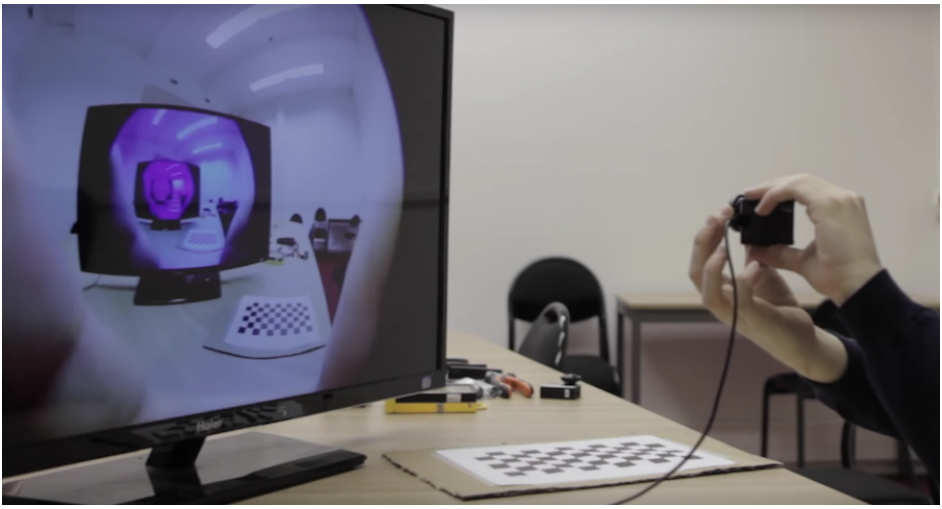
Step five. Clean up the glue from the lens mount using your screw driver.

Step six. Add the lens collar to your new fisheye lens.

Step seven. Insert and screw the new fisheye lens to the body of your GoPro.

Step eight. Put the battery in and connect your GoPro to a monitor using an HDMI mini to HDMI cable.

Step nine. Calibrate the focus by holding a checkerboard print or resolution chart in front of the lens, and screw the lens until perfect focus is achieved.



Step ten. Lock the focus by screwing the lens collar with the flat screwdriver until the lens is locked and unscrewable by hand.

Dymaxion Chronofile

"So, planners, architects, and engineers take the initiative. Go to work, and above all co-operate and don't hold back on one another or try to gain at the expense of another. Any success in such lopsidedness will be increasingly short-lived. These are the synergetic rules that evolution is employing and trying to make clear to us. They are not man-made laws. They are the infinitely accommodative laws of the intellectual integrity governing universe."

- Buckminster Fuller, Operating Manual For Spaceship Earth

Problem:

You have devils of details to worry about.

Be organized! Number your cards as well as cameras. Color code your cameras if you have **Multiple Rigs**. This will prevent headaches and confusion during **Ingestion** and post production. There are all the normal problems of shooting times x amount of cameras so proceed with extra care. Remember to give yourself **Reference Signals** for **Synchronization** during post. Prepare for the shoot by **??**, resetting the **??** on all your cameras, and charging extra batteries.

Solution:

Get a journal or notebook to keep track of production notes, takes, the month and date of each new morning, and share your growth!

We hear the phrase “new cinematic language” everyday. What does that look and sound like? A single person alone can’t write an entire language. Then there would be no dialogue. We need to all create grammar, vocabulary, words, sentences, poems and build the structure together. Share and compare your findings. New words arise from a common need. Let’s write!

problems of stitching

Ingestion

Problem:

You want to see how your footage came out but need to transfer all the data before quickstitching.

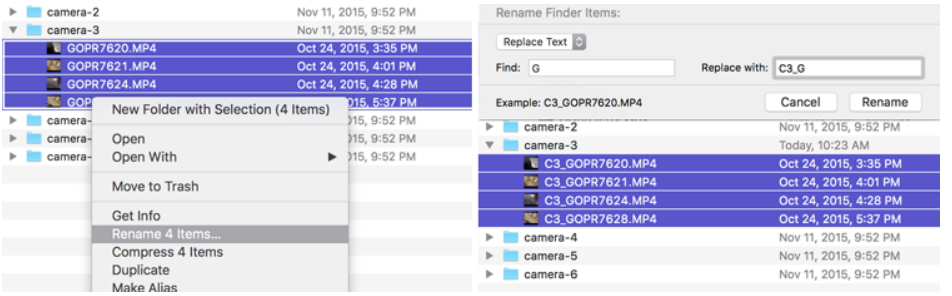
Whether you want to check the lighting on set with a quickstitch test or you are ready to head into post production, copying all the data files is required before stitching. If you have a **Realtime Preview**, record the input with a capture box for a rough **Dailies Quickstitch**. Otherwise, there is no method for viewing the takes without ingesting the footage and quickstitching.

Solution:

Ingest Manually.

Each SD card corresponds to a certain camera angle. When you ingest video files from one SD card, you are uploading all the takes into one folder (ex. Camera 1, Camera 2). You will need to move the videos from each camera folder into a new take folder (ex. Take 1). Here's a snapshot of how it looks before and after.

PROTIP: Before selecting the files to move to take folders, batch rename the files with the camera number as a prefix. For example, select the letter G from Gopro, and rename all files with Cam1_G. In the next camera folder, you just have to change Cam1_G to Cam2_G.



To quickly find which video files should be placed into a new take folder, open all your camera folders using the dropdown arrow. Start by highlighting the first mp4 in each camera folder, then look at the file size of each one. If it's the same or close in size for all highlighted files, the files are all from the same take. Drag them all into the new take folder. If you are unsure, you can always open the videos and view them.

Renaming source files later can be tricky, so organize before stitching. Is your project stereoscopic or monoscopic? If you shot in stereo, you will have two of each camera angle, corresponding to left/right eyes. Make sure to include if the video is Left eye or Right eye in the filename.

The simple saying "for every minute spent organizing, an hour is earned" truly applies to 360 video editing. Remember you are editing the amount of take files times the number of cameras. Add a few prefixes to help you and your team down the line such as T01 for take number, HD or SD (4K/2K), C01 for camera number, LE or RE for Left Eye and Right Eye in the case of stereoscopic projects.

GOPR02355 would be T01_HD_C01_GOPR02355.mp4 for a monoscopic project.
GOPR01025 would be T07_4K_C03_LE_GOPR01025.mp4 for a stereoscopic project.

PROTIP: Mac Users can right click to use the “rename files” option after highlighting all the files in the take folder. For PC users, you can use a third party tool like Bulk Rename Utility.

Import all GoPros with AVP.

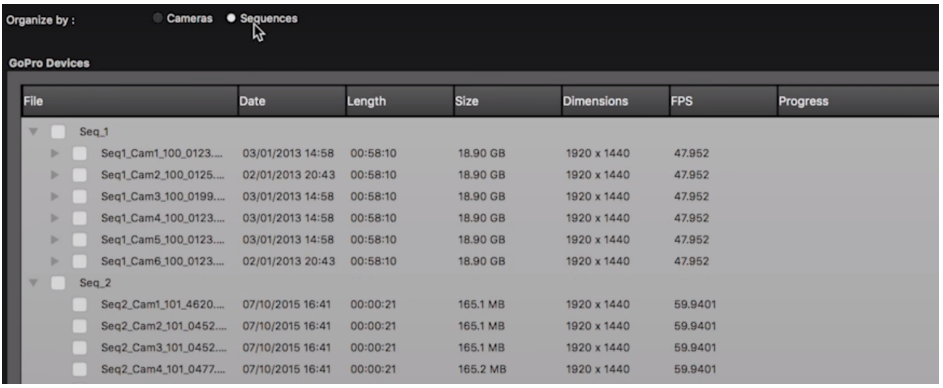
With the recent release of AVP 2.3, ingesting files got a whole lot easier. You will need to purchase a couple of Lexar Workflow multi-slot card readers. MTP is not supported.

The process is simple. When you are done shooting or if you need to do a quick on-site stitch, insert all your SD cards into the multi-slot readers. Use a USB hub if shooting with a lot of cameras like the stereo or cylindrical rigs.

Open AVP and under File, select Import all GoPros.

One of the major pains is the splitting of longer takes from the GoPros. When files reach the 4 GB limit and the recording continues, the take will be split into multiple files that need to be to concatenated. With AVP 2.3, concatenating files is handled internally during ingestion. You will see small dropdown arrows for all large sub-sequences that AVP detects.

At the top of the ingester, display your files by sequence. Then check "merge successive chapters" and "create subdirectories" at the bottom. Now you are ready to ingest. Enter the path location of your source folder instead of the desktop. For example LACIE/ProjectName/Source/Video/. Then "Transfer Selection" and let AVP concatenate and ingest all of your sequences, also called take folders.



Your files will be merged and renamed with minimum manual organization needed. You may want to batch rename the files in each take folder and add additional prefixes such as LE, RE for stereo footage or ShotN_SceneN_TakeN.

PROTIP: When ingesting using AVP, make sure you have the exact number of takes in each of your SD cards and all **Misfires** have been deleted. You may encounter problems with this way of ingesting if you didn't reset the **World Clock** on your GoPros. This ingestion method is still in beta, so double-check everything before transferring the files.

Dailies Quickstitch

Problem:

You need to quickly stitch some source footage with burnt in timecode for a review session but don't know where to start.

You've just finished the **Ingestion** process and organized your source footage onto a hard disk after shooting multiple takes for many scenes. It's now time to sort and label your files into bins. As opposed to the traditional post-production workflow, reviewing your dailies can't happen until your footage is stitched together. Stitching two or more videos together will first require you to organize your files properly.

Solution:

AVP + APG.

Most video camera manufacturers are developing built-in functionality to ease the stitching/playback of 360 dailies. If you don't have a **Realtime Preview** solution, you will have to stitch the videos yourself before previewing dailies. Thanks to Autopano Video Pro (AVP) from Kolor, it's just a few clicks away.

Autopano Video Pro or AVP is the go-to video stitching software and industry standard. It takes at least two videos for the stitching process to occur. Since stitching videos is an intensive task for most of today's GPUs and CPUs, AVP has a "sister" software. Autopano Giga or APG is the advanced stitching tool for combining multiple images into a panorama.

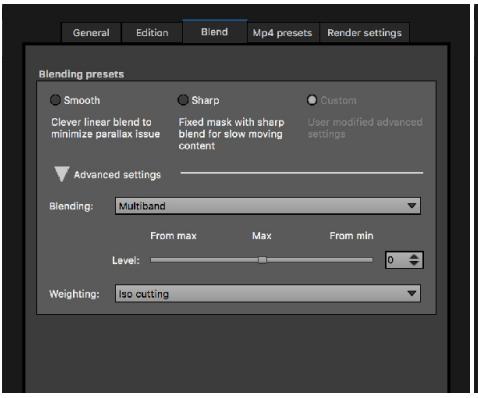
To stitch multiple videos into one panoramic video, AVP will extract a frame from each of your videos as a JPG image. These images will be

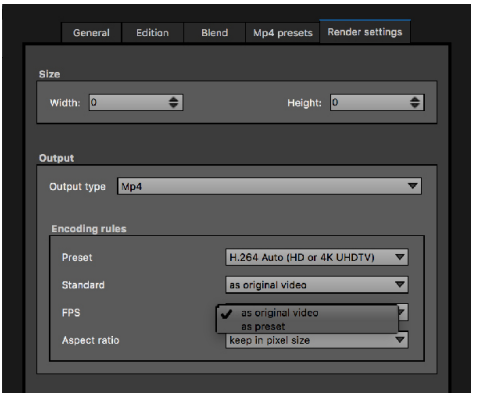
stitched together based on a selected calibration. You can select a different frame by moving the cursor on the timeline, and AVP will re-extract the newly selected frame from each video stream. After stitching the different images, your panoramic video will be stitched based on the stitch quality of the frame selected.

T001	Nov 3, 2015, 7:11 PM	--	Fold
T001_HD_C00_GOPR0020.pano	Nov 3, 2015, 7:13 PM	673 KB	Aut
T001_HD_C01_GOPR0025.MP4	Jan 2, 2015, 6:41 PM	436.6 MB	MPI
T001_HD_C01_GOPR0025.MP4.jpg	Nov 3, 2015, 7:11 PM	1.4 MB	JPE
T001_HD_C02_GOPR0025.MP4	Jan 12, 2015, 8:51 PM	437.3 MB	MPI
T001_HD_C02_GOPR0025.MP4.jpg	Nov 3, 2015, 7:11 PM	2.3 MB	JPE
T001_HD_C03_GOPR0025.MP4	Jan 2, 2015, 6:41 PM	436 MB	MPI
T001_HD_C03_GOPR0025.MP4.jpg	Nov 3, 2015, 7:11 PM	1.6 MB	JPE
T001_HD_C04_GOPR0026.MP4	Jan 2, 2015, 6:41 PM	436.9 MB	MPI
T001_HD_C04_GOPR0026.MP4.jpg	Nov 3, 2015, 7:11 PM	2 MB	JPE
t1.kava	Nov 3, 2015, 7:13 PM	39 KB	Aut

When the stitch quality is not perfect throughout the video, use APG to edit the stitch manually with the use of **Control Points** or **Masking Markers**. In APG, you will have the option to auto-update your stitch in AVP by saving your stitch template. The template holds metadata that allows AVP to stitch your videos based on your adjustments in APG.

PROTIP: Before you start stitching, it is best to check the preferences of AVP. Under Blend > set Blending Level to 0, Weighting to ISO Cutting, and under Render Settings > set FPS as original video. Later on, you may also want to add different presets for your renders, helping you speed up your own workflow.



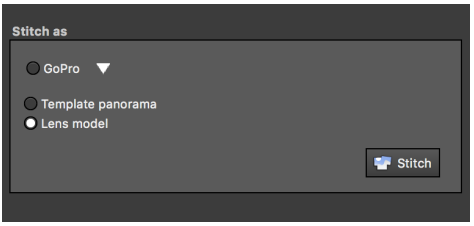


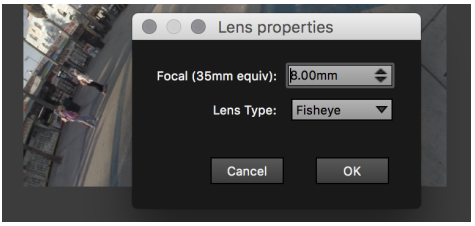
Synchronize. Calibrate. Stitch.

Drag your videos into AVP. All videos must have the same format (mp4 or mov) and same frames per second (FPS). The accuracy of the visual sync between cameras may vary depending on the equipment used, or your **Set and Settings**. Ensure all cameras are perfectly synchronized before stitching. Apply "Use Audio to Synchronize" under Synchronization menu, after selecting a frame of your timeline.

Before jumping onto the stitch tab (fourth icon in the AVP header bar), select a range of frames by trimming your timeline at the beginning and end using the blue range selector. Use "I" for IN and "O" for OUT frame with AVP 2.3. Then click on the exact frame you want for the calibration. Don't leave it on the beginning frames. You don't want to confuse AVP by trying to stitch the DP's fingers or face. Save that for later during the fine stitch.

Select a stitching preset using the dropdown. The default preset will auto stitch as GoPro. If you are using different camera lens, check "Lens model" and input the focal length and lens type. For example, enter in 8mm for your focal length and fisheye for type of lens. Press "OK", then click "Stitch" and let AVP do the rest!

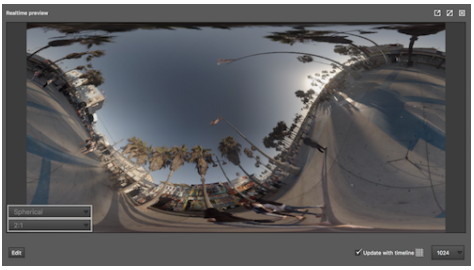




Bravo, you have just completed your first quickstitch!

Re-Orient. Optimize. Render.

When stitched together, your panoramic video may need to be adjusted or rotated. Hold your cursor on the preview area and drag until the horizon is aligned. Don't forget to apply your changes. Press "A" to apply with AVP 2.3.

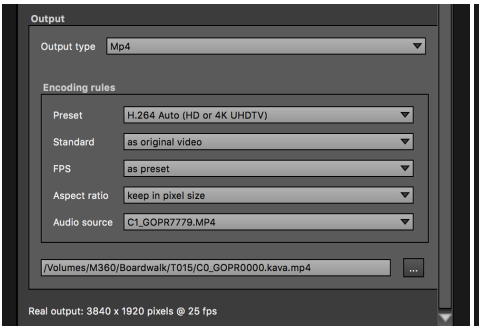


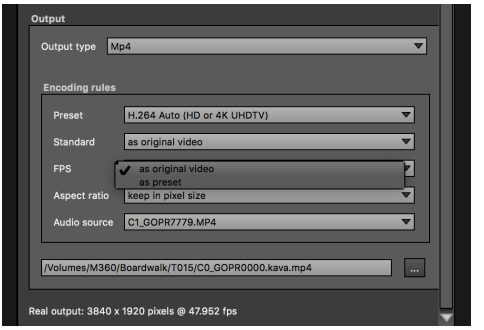
Select the Blend icon to better optimize the blending of your videos. For static or landscape shots, try the SMART cutting and you may be impressed by how the quality of the stitch will improve. For most shots, when the camera is moving or if you have moving subjects, ISO cutting is recommended.

Rendering is the last step in the workflow. Every software you use to edit the video or audio of a file will let you export the changes by creating a new video or audio file with the render settings you selected.

Before you start rendering, double check that all your default preferences are correct. Consider the right FPS for the playback solution of your choosing. Even if you shot at 100 FPS or 60 FPS, you will want to output at an FPS that the headsets or video player can handle.

For example, if you want to upload your 360 video to YouTube or Facebook, the current allowed FPS is 24, 25 or 30. For quick stitches, set the FPS to be same "as original video" under the Render settings. Setting the default preferences will make it easier to batch render.





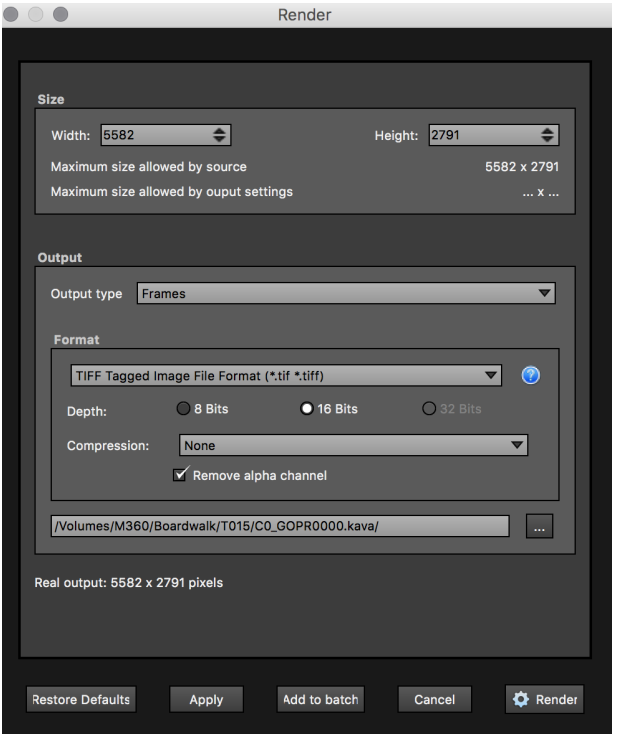
When you are ready to hit the "render" icon, AVP will bring a pop up of some presets to choose from and show the maximum output size. The maximum output size is the resolution achieved from your 360 camera rig. Depending on the rig you chose, the final resolution after stitching can range from 4K to 12K. Presets are very valuable during stitching and you will want to get familiar with all the choices. When you want to render small files quickly to test and find seams to fix, you can output at a lower resolution such as 2K. You can always check at the bottom of the pop up window what resolution and frame rate the video will render as. For the Gear VR, render your videos at 3840x1920 or 4096x2048 when shooting 4K (1920x960 is SD).

Fine Stitch Rendering.

When rendering your fine stitch, it is highly recommended to render output type as frames, a sequence of uncompressed tiff images at 16 bit color depth. Rendering frames keeps the highest possible resolution of your panorama at the maximum size allowed. There are limitations when you render videos. The bit depth will be between 8 to 10 bit, including the AVI uncompressed option, and there are size limits (for example: H.264 mp4 maximum height at 2304px). Your footage will be running through many processes down the pipeline. From stitching to VFX to editing to color

grading, pixels will get distorted down the line. Distortion occurs within the range of 10-16 bits.

Starting with Autopano, you will want to work on the highest resolution files to minimize distortion of colored pixels and keep the full quality when rendering an 8-10 bit per channel video. Output tiff Frames at 16 bit and no compression in AVP.



PROTIP: Removing the alpha channel when exporting tiffs will reduce the size of each tiff. Recommended for large sequences.

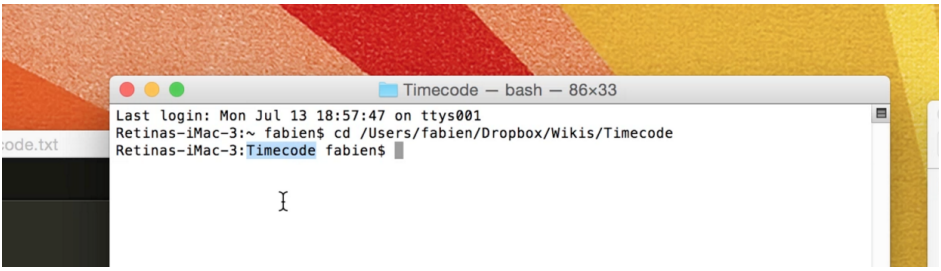
Every time you render, you are creating a new file. Stay organized so you know what version each render is. Add a prefix to every file. Use QS for Quickstitch, a version number _v001 for your tests, and FS for Fine Stitch. When rendering frames, select an output folder with the suffix _tiff in the name.

Encoding a burnt-in timecode

You can use After Effects, Premiere or any video editing software to encode a timecode or you can do it...the "hard" way aka not really, just the geeky but in reality faster way! **Hello FFmpeg**! Don't let the terminal or command lines scare you!

For Mac users, the "drawtext" filter of FFmpeg is only working with a specific FFmpeg binary. Refer to **Hello FFmpeg** to install the right binary.

Open the Terminal app on Mac, Command Prompt on PC. Use the basic commands to access the directory where your stitched video is located.



PROTIP: On Mac, if your Finder is opened with your video visible, drag the folder icon into the Terminal window AFTER typing "cd" (e.g. change directory). On PC, click the folder icon to reveal the path, and paste it in your Command prompt after "cd".

Type the exact FFmpeg script for the action you want to perform on the video: embedding a timecode in center of video, at the same frame rate as video.

Run FFmpeg by simply typing "ffmpeg" in the terminal. FFmpeg takes a video in and creates a new video out. Let's tell ffmpeg where and which video you want as input. Just type "-i" and the path/name of your file.

```
ffmpeg –i video.mp4
```

Type the name for the output file. This FFmpeg script doesn't really perform

any action besides renaming the output file. If you want to change the extension of the output filename to .mov, FFmpeg will operate a conversion of your video from MP4 to MOV.

```
ffmpeg -i video.mp4 video_tc.mp4
```

To add any kind of text or timecode on your video, use the filter "drawtext" after calling it via -vf command before the output, such as:

```
ffmpeg -i video.mp4 -vf "drawtext=" video_tc.mp4
```

Select a monospaced font file from your machine:

```
fontfile ='/ Library/Fonts/Arial. ttf ':
```

Then add the format for the timecode including the frame rate (matching same FPS as video), font size, color, and position on the video:

```
timecode='00\:00\:00;00':r=29.97: fontsize=32: fontcolor=white: x=(w)/2:y=(h)/2
```

Note the colons are required between each argument. Put all of this together into one command line:

```
ffmpeg -i video.mp4 -vf "drawtext=fontfile='/Library/Fonts/Arial. ttf ':
timecode='00\:00\:00;00':r=29.97:fontsize=32:fontcolor=white:x=(w)/2:y=(h)/2" video_tc.
mp4
```

Press RETURN after pasting this line into your Terminal and FFmpeg will render the video again with the timecode on it. Good Job!

If you get an FFmpeg error message of "Drop frame is only allowed with 30000/1001 or 60000/1001 FPS" that means your video clip is using a non-drop frame based timebase such as 24/25/30/60 fps. To fix this issue, you will have to change the FFmpeg timecode string value to `timecode ='00\:00\:00\:00'` and adjust the r=29.97 timecode frame rate setting to match your current video clip's frame rate.

With FFmpeg on Linux the command is:

```
ffmpeg −i video.mp4 −vf "drawtext=fontfile=’/usr/share/fonts/dejavu/DejaVuSans.ttf’:
timecode=’00\:00\:00;00’:r=29.97:fontsize=32:fontcolor=white:x=(w)/2:y=(h)/2" video_tc.
mp4
```

With FFmpeg on Windows the command is:

```
ffmpeg −i video.mp4 −vf "drawtext=fontfile=’C\:\\Windows\\Fonts\\arial.ttf’:
timecode=’00\:00\:00;00’:r=29.97:fontsize=32:fontcolor=white:x=(w)/2:y=(h)/2" video_tc.
mp4
```

Note the fontfile path on Windows needs to have each of the directory slashes escaped with a double slash, and the colon in the drive letter needs to be escaped with a slash as well.

First Assembly

"23. Keep track of every day the date emblazoned in yr morning"

- Jack Kerouac, Belief and Technique for Modern Prose

Problem:

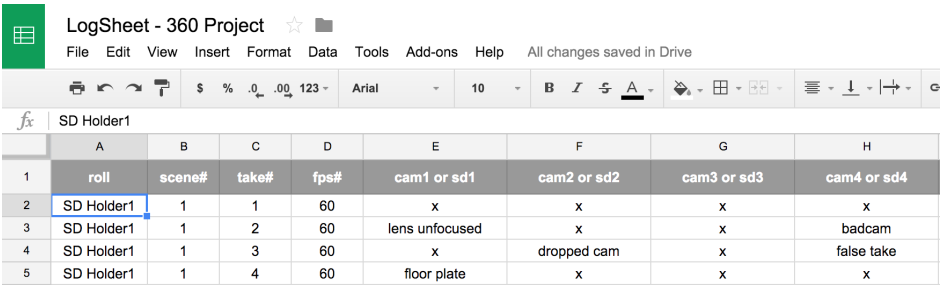
You need to assemble a rough cut with multiple unstitched video streams.

You have just rendered the quickstitches with burnt in timecode and have to select the best parts for your edit. Should you edit with the source or the stitched footage? How should you log notes for the best 360 edit?

Solution:

Log notes from reviewing quickstitches.

Whether viewing the dailies with the crew after each day of production or during the director-editor viewing session in a headset, always log notes with the 360 space in mind. When auditioning for the best material, consider which camera the viewer will be facing when putting the headset on. Have your log sheet ready with one row per camera.



	A	B	C	D	E	F	G	H
1	roll	scene#	take#	fps#	cam1 or sd1	cam2 or sd2	cam3 or sd3	cam4 or sd4
2	SD Holder1	1	1	60	x	x	x	x
3	SD Holder1	1	2	60	lens unfocused	x	x	badcam
4	SD Holder1	1	3	60	x	dropped cam	x	false take
5	SD Holder1	1	4	60	floor plate	x	x	x

The log sheet will evolve over the entire 360 editing workflow, so make it clean and beautiful! During ingestion, have the DIT start this sheet by adding a column for each camera, a row for each take and some notes such as “bad cam”, “false take”, “dropped cam”, etc. After organizing your camera files into take folders, update this log sheet and below each take, add as many rows as the number of cameras.

	A	B	C	D	E	F	G	H	I	J
7	**cam#**	**scene#**	**take#**	**fps#**	**sync offset**	**in point**	**out point**	**ev comp**	**stitch notes**	**notes**
8										
9	1	1	27	29.97	0	557	1684	-	lens flares	x
10	2				0			-	-	x
11	3				0			-	-	x
12	4				0			-	lens flares	x
13										
14	1	2A	23	29.97	0	4578	5958	-	lens flares	lens unfocused
15	2				0			too dark	-	x
16	3				1			-	-	x
17	4				0			-	lens flares	badcam
18										
19	1	2B	6	29.97	3	577	2166	-	lens flares	x
20	2				0			-	-	dropped cam
21	3				3			-	-	x
22	4				0			-	lens flares	false take
23										
24	1	3	2	29.97	1	4464	5707	-	lens flares	floor plate
25	2				0			-	-	x
26	3				0			-	-	x
27	4				0			-	lens flares	x

The goal of the log sheet is to track the INs and OUTs of all your selects, the cameras that need some exposure correction, the synchronization offsets, the location of files and all other notes from the team. The log sheet will be extremely helpful for the stitcher, editor, and director.

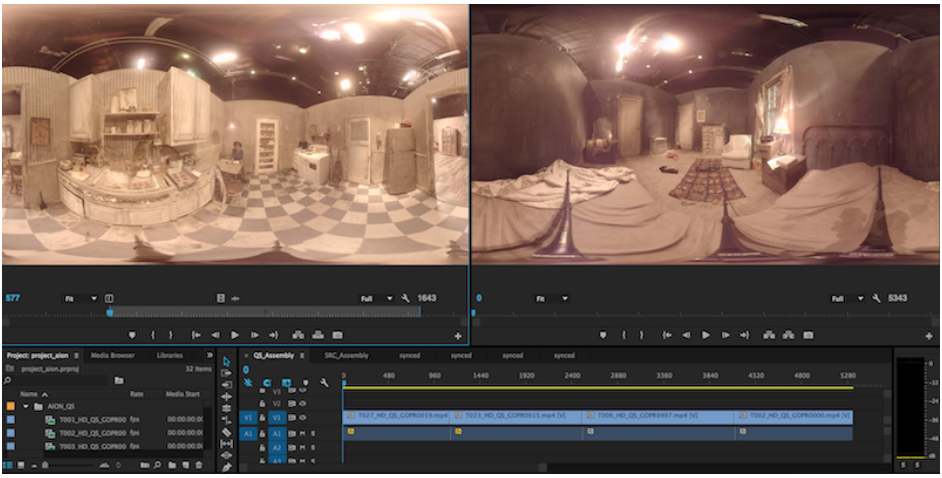
Put it together, stitched + unstitched.

As a rough draft, the first assembly usually will have the least amount of cuts. In 360, it’s not optimal to have a lot of fast cuts and transitions. The viewer will need slow transitions to ease into the new environments. Your assembly will contain as many video/audio tracks as the number of cameras in your rig.

First, use the quickstitches to build an edit. This method is similar to the traditional rough cut edit. Bring all your quickstitches into Premiere, use the shortcut I for IN and O for OUT to reflect the log sheet’s INs and OUTs selected by the director. All quickstitches should be synced and untrimmed

to reflect the same timecode as the source footage you will be editing later.

When assembling all clips in your timeline, focus on the timing of the transitions. Give the viewer enough time to adjust to the new scene. Then edit all your best clips in the order you desire. When satisfied with the first assembly of the quickstitches, render a low resolution preview of it or start the next phase, assembly with the source footage.

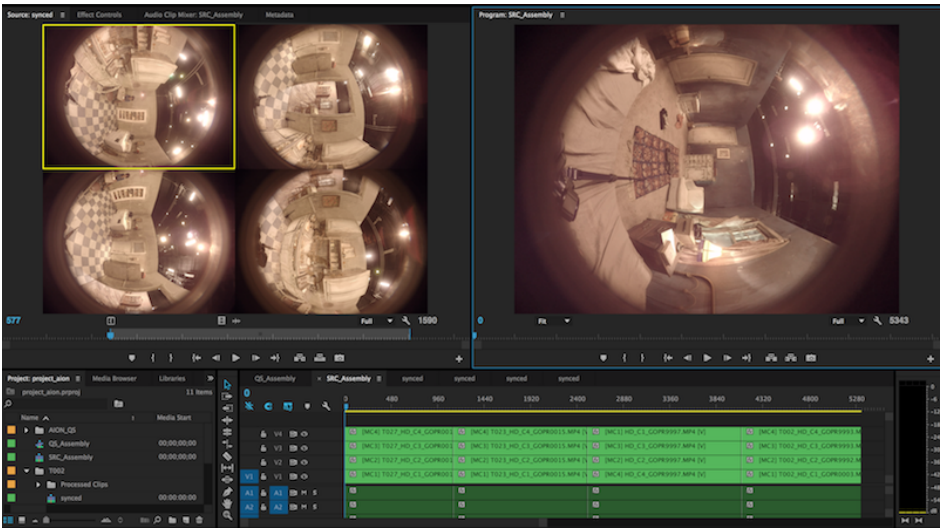


Assembly with the source footage will require one video track per camera and should precisely match the rough cut edit of the quickstitches. Make sure the quickstitches are properly named with the take and camera number. This will make it easy for you to locate the cameras that correspond to each clip in the timeline. Select all the cameras of each take, and sync them using the multi camera **Synchronization** through audio.

Bring the synced sequences of source footage to a new timeline with the settings matching the camera settings. Trim based on the IN and OUT points of your log sheet and assemble them like the previously stitched first assembly. It's crucial to keep the same settings as the source video to avoid any compression.

If you shot plates or created titles and other VFX, you can easily add a video track over the source video track to create the final result you are

trying to achieve even before stitching it.



The assembly using source footage is not for preview purposes, but for exporting the EDL or XML file. The EDL file or Edit Decision List is a file that many editing softwares read in order to recreate the same exact timeline after relocating the project folder and files. If your individual cameras will require **Color Matching** or if the content of your individual cameras were not shot at the same time, exporting the EDL from the source footage will help you more than exporting the EDL from the quickstitch assembly.

The purpose of the **Dailies Quickstitch** is to review and approve the shots for the first cut. After the shots are approved, the focus can turn towards fine stitching the selects. This minimizes render time and also saves time so the stitcher fine stitches only the takes needed. The most optimal workflow for the stitching post production pipeline is to quickstitch all the footage, choose selects, then fine stitch the selects.

PROTIP: If the content of your individual cameras were shot at different times but you are editing quadrants shot from the same camera position and location, you can render the video tracks separately and stitch it all in one take.

Color Matching

"Light or luminosity is created by the way elements are juxtaposed. They become reflective and a radiance comes from putting different things together."

- Merce Cunningham

Problem:

One camera is too bright or dark, affecting the overall blending.

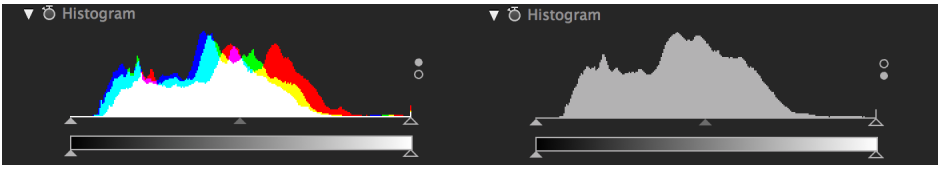
Pure white reflects 100% of the light, while pure black reflects 0% of the light. Any camera's metering system wants to meter everything as middle gray, usually around 18% gray. Exposure compensation is a challenge during production, as it reflects 18% of the light that is cast upon it. This is an even bigger challenge when shooting in 360 degrees.

When correcting exposure of a camera in post production, figure out what happened in production. Was the shot overexposed? Was white balance set to auto? Exposure compensation adjusts brightness within the existing ISO Limit. If brightness has already reached the ISO Limit in a low light environment, increasing your exposure compensation will not have any effect.

Correcting overexposed or underexposed footage with the Exposure plugin from AE or Premiere is not the way to go. Here is a good alternative to keep the bit depth of your colors at its highest.

Solution:

Read the RGB histogram.



Learn how to read and understand RGB histograms. R G B, red, green, blue, these 3 primary colors make up your image. Lows, mids and highs are color ranges that correspond to your low lights, also called shadows, mids and highlights. The histogram is a representation of the distribution of the colors (or pixels) in an image.

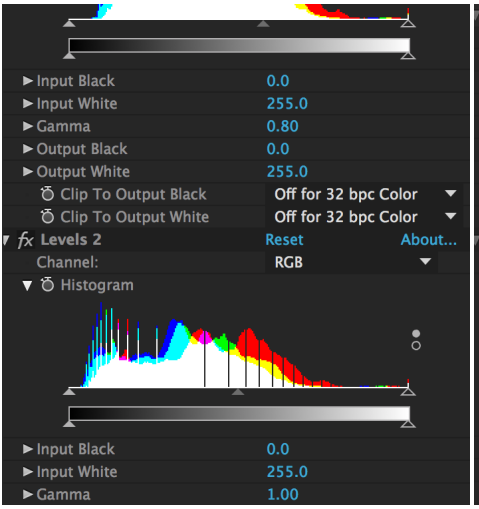
There are two histograms. The main color histogram shows the red, green and blue channels (the actual real data) and the one channel combined value histogram is only a simulated computed value called luminosity. Use the color histogram or select an individual channel to adjust instead of the combined histogram.

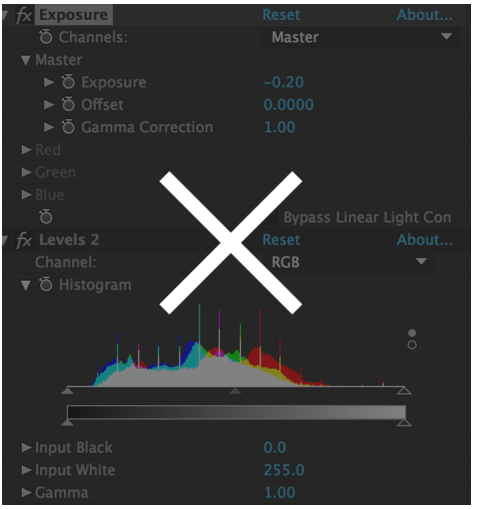
You can read an overexposed shot by comparing the red, green and blue channels, and finding one or more spikes in them. A red spike in the highlights range would mean your shot was overexposed maybe by two thirds and correcting the levels of reds would help balance all colors in the image.

Level gamma .2 up or down.

Exposure compensation is a parameter you need to control during shooting and production while gamma correction is for post manipulation of your image. To compensate for the exposure in post production, tweak the dynamic range of color, gamma levels, or the digital interpretation of “exposure”.

Since exposure compensation in AE or Premiere is a linear global function, it's safe to use the gamma levels (left image below) along with its color histograms, as these are non-linear global functions compressing the dynamic range.





In AE, bring all the source footage into one composition and align them horizontally with 5-10% overlap over each other. You can color match or exposure match all the overlapping areas or edges with this setup. When stitching, the overlapping areas will then blend much better. The pixel colors of the edges will be easier for Autopano's algorithm to interpret. Additional control points can be found by adjusting the gamma on a shot that is over or under exposed.

Apply the plugin “Levels” on each of your video layers and review the histogram for every layer. Take note of the spikes, which will help you understand how to accurately gamma correct.

Adjust the gamma’s mid level, by .2 points up (to the right) or down (to the left). Try not to adjust the individual color channels, as this distorts colors too early in the post production workflow.

Finally, render a lossless .mov file instead of compressing and rendering another mp4.

Synchronization

Problem:

The cameras are out of sync, causing a bad stitch.

To stitch a moving or static shot with moving objects or people, you will encounter magic you didn't expect, such as people disappearing randomly, or getting shrinked as they cross cameras, or you may think you're seeing double. Few causes can explain these surprises. Usually it is a sync related issue. If one or more camera starts shooting with a slight delay, you need to resync in post.

Solutions:

Use Autopano's built in synchronization.

Synchronizing your videos is the first step before the footage is ready to stitch. After dragging your videos into AVP, use the built in synchronization. This feature only works if there were **Reference Signals**, like an audio or motion signal recorded at the start of the take during the shoot. In some

situations, there is no audio or visual signal for sync. For example, if you shot the camera angles at different times, the shooter forgot to audio slate, the audio on the cameras got dropped, or there was no speedlight for a motion flash that day, etc. In these extreme cases, manually input the offsets of the videos needed to be stitched. Find a visual sync frame and use one camera as an anchor. Look for a frame with fast moving motion, such as legs running or hands clapping, and match the rest of the cameras.

After dragging your videos into AVP, find the Synchronization tab and open it. Select the closest frame in your timeline to a “clap” or any high peak in the audio signal.

AVP lets you select the range in seconds for the auto detection to happen, 20 seconds being the good average. Select “Use Audio to synchronize” option and click Apply.

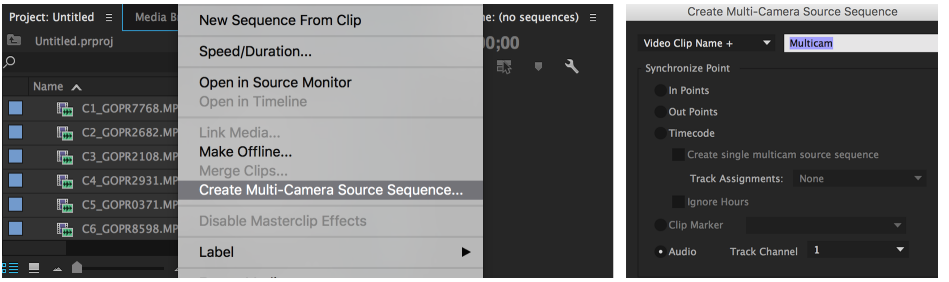
The second option “Use Motion to synchronize” will only work if you used motion or a speedlight flash during production. Select the nearest frame and a range for AVP to auto-detect the flash or motion in each of your videos.

Auto sync with Premiere’s multicam sequence.

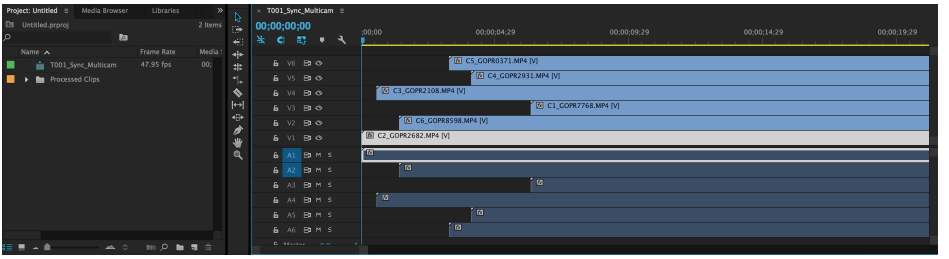
Adobe Premiere’s auto sync function for multiple cameras is similar to RedGiant’s PluralEyes software, and very accurate. As opposed to AVP, when Premiere can’t sync it will warn you. Then you will know when you

have to manually sync the videos.

Instead of creating a new sequence, find or drag all your videos in Premiere's project section, right click and select Create Multi-Camera Source Sequence. Then choose "Audio" as a synchronize point and "All Cameras" for the audio sequence settings.



Your videos will be processed and placed into a bin. Rename the created sequence based on your log notes. Right click and Open the Multicam sequence in the timeline to see how the video tracks have been synced.



If you are editing your **First Assembly** with Premiere, it may be a good idea to update the files/folder names between your quickstitches and your source cameras. Add a shortcode such as SYNC, QS for Quickstitch, FS for Fine Stitch, CC for Color Corrected. Rename the "Processed Clips" folder to the shot name and include all needed and related assets in the bin folder.

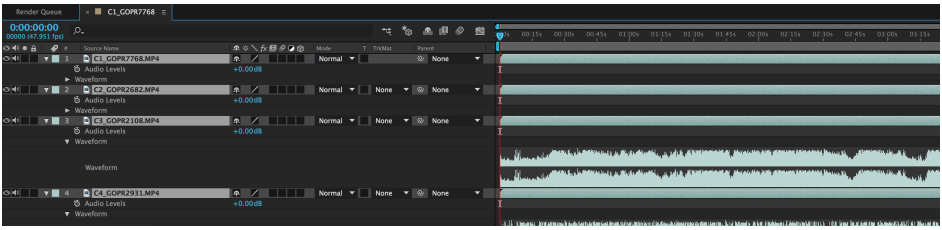
Manually sync in After Effects.

Bring the videos into AE and use the cursor line on the timeline to sync the audio streams of the different cameras.

Open the “preferences” of AE, and set Import > “Sequence Footage” to your project FPS. Then File > Save as... your project to the location desired.

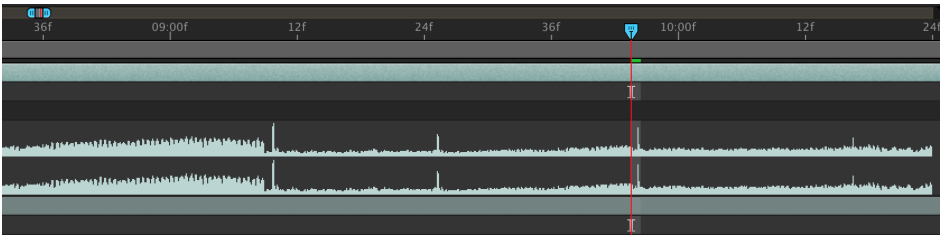
Import all the cameras into AE and create a single composition with all the videos.

Press “L” after selecting all layers to show the audio levels, then click on the triangle to open the waveform, one layer after another.



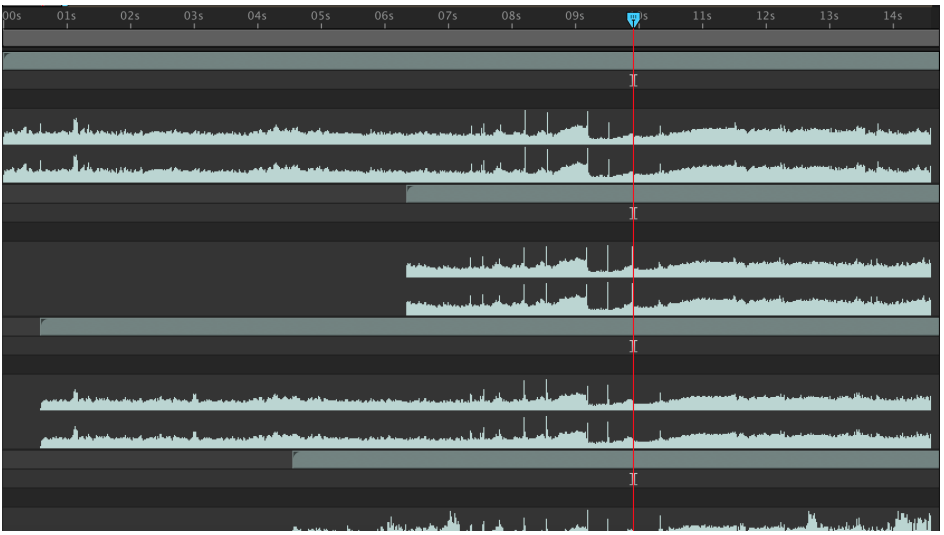
You can minimize your video area to focus on audio sync.

Find a peak in the waveform and place your cursor just before that peak. You can use any other reference, but peaks are easier to detect and align to.

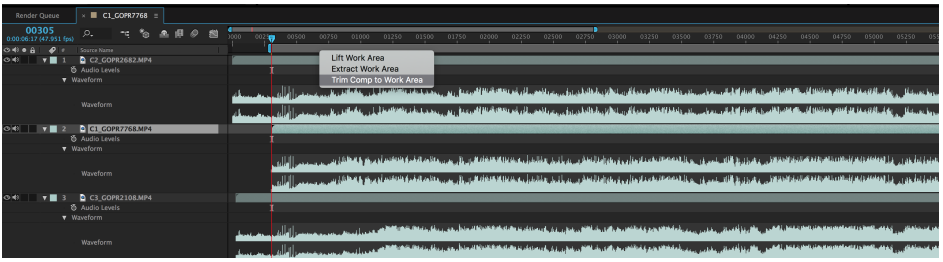


The red line below your cursor will help you see how to move the video stream to the left or right (forward or backward in the timeline).

After aligning the layers based on the audio peak in the waveform, zoom in to the timeline for accuracy.

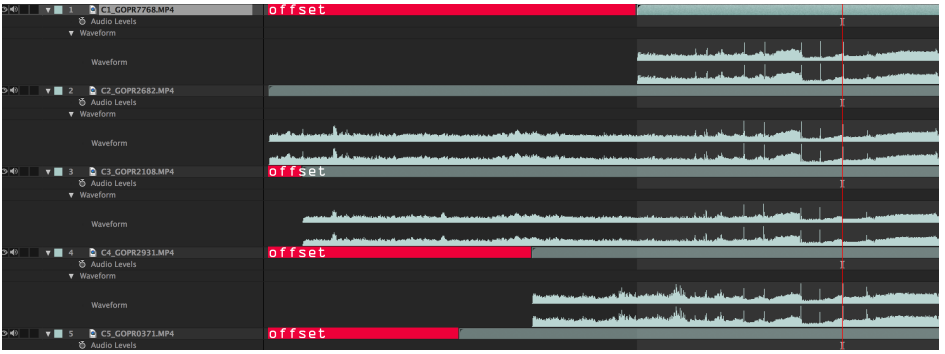


Now you have two options: trim the videos and render only the footage in sync, or record the sync offset of each video track. Let's trim in this case and render the new video stream now synced and ready for stitching.



Recording the offsets

The video track with the largest distance from frame 0 will be the origin. The offset for that video track is 0. The opposite and longest video track, usually untouched with start frame at 0, will need to be offsetted by the number of frames between its start frame and the start frame of the video track with largest offset. For this example, it is 305 frames.



For all other video tracks, subtract the start frame of each video track by the largest offset. For example:

C1: Start Frame = 305; Offset = 305 - 305 = 0
C2: Start Frame = 0; Offset = 305 - 0 = 305
C3: Start Frame = 28; Offset = 305 - 28 = 277
C4: Start Frame = 218; Offset = 305 - 218 = 87
C5: Start Frame = 158; Offset = 305 - 158 = 147
C6: Start Frame = 69; Offset = 305 - 69 = 236

Log the offset of each video track and input them in the Synchronization section of AVP.

Syncing your videos is a basic required step before stitching. Make sure to double check the sync offsets or you may end up spending hours trying to fix a stitch when it was really a sync issue. AVP makes it easy to sync in the software, but it is best to manually check the sync offsets are spot on with an alternative solution.

Background vs Foreground

Problem:

While trying to fix the stitch, you broke the background by adding control points on subjects close to the camera.

Most of the time, you will not be able to fix all the seams with only one stitch template.

Autopano automatically extracts a frame from each camera, allowing you to edit the stitch calibration of the specific frame chosen. When you update the calibration for one frame, it will update and apply changes to the entire video. After previewing the video, a seam is still seen by a person crossing through it. Should you fix the person crossing or the seam in the background?

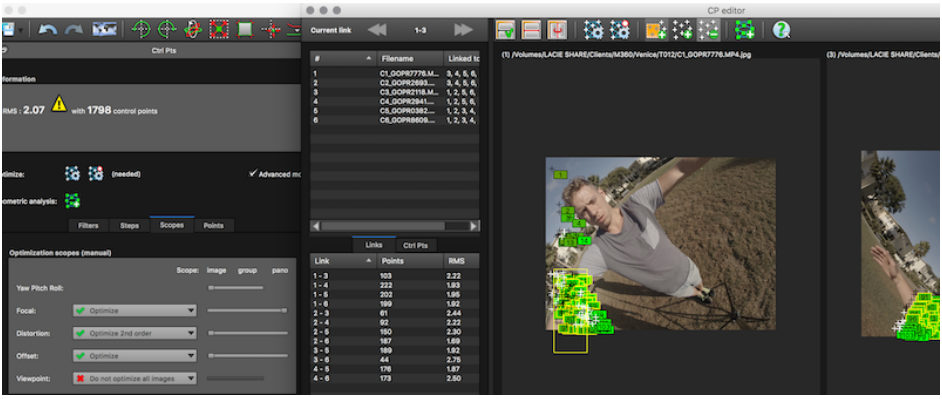
Solutions:

Depending on the rig you chose, parallax can be increased or reduced. When both foreground and background contain essential objects or subjects, it is necessary to split your work into two stitching phases. Stitch the background first. Render. Stitch the foreground second. Render. Comp them together.

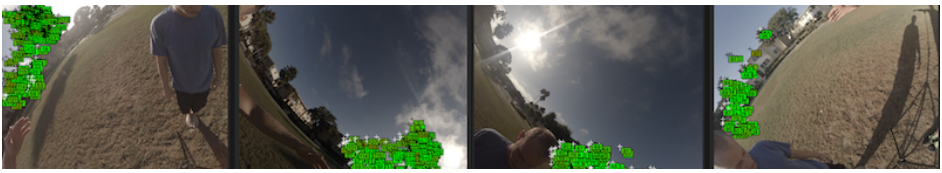
Background approach.

Subjects that are too close can't be fixed when stitching the background. Focus on the distant background. Select the frame with the most seams. If it's a static shot, any frame will do. If it's a moving shot, preview the quickstitch to help select a frame.

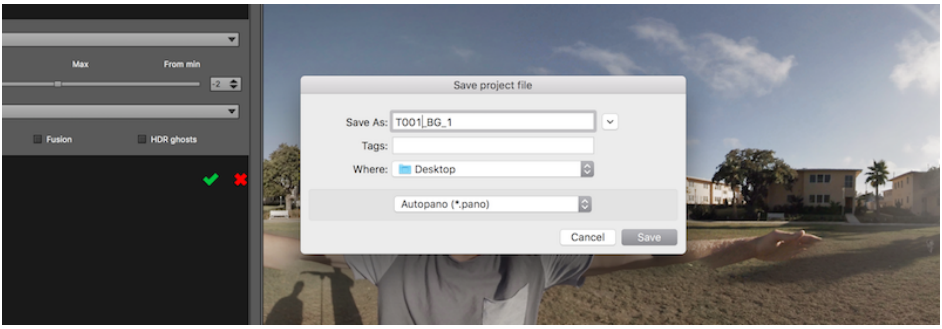
Leave the close objects or subjects distorted and focus on the distant seams. In the advanced settings of the control points editor, move the slider for Distortion and Offset scopes to Image and select Optimize to 2nd Order from the Distortion dropdown.



In each set of images, remove the auto-detected control points on close objects and subjects. Don't forget to "Quick Optimize" the calibration.



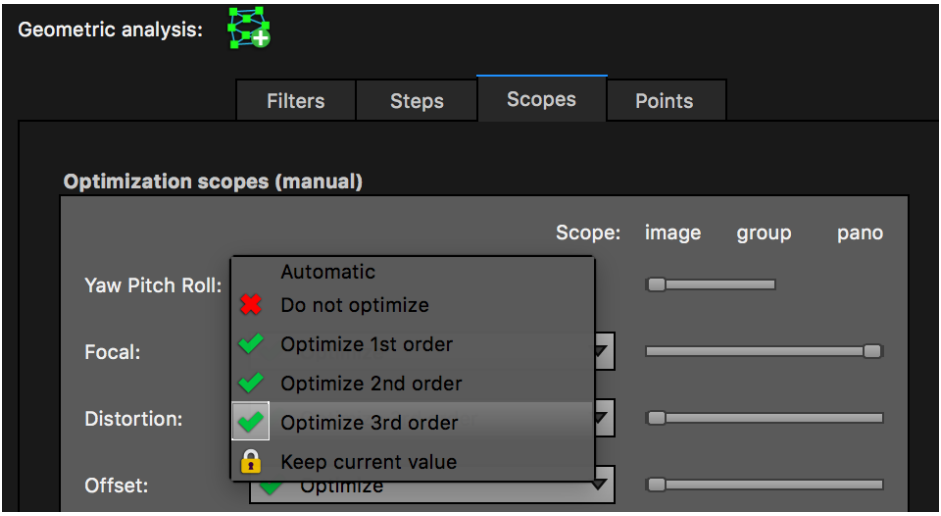
Save your project and add a version number, for example, T001_BG_1.kava. Keep different stitch templates in your take folder to help you stay organized and save time for future adjustments. Render your work.



Foreground approach.

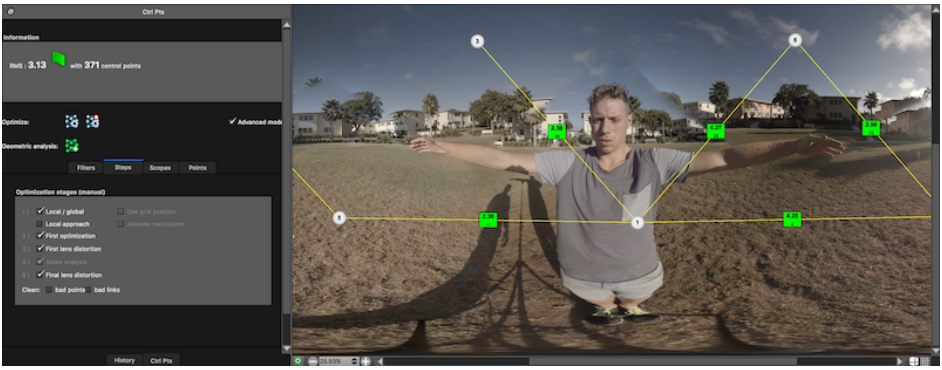
There are many creative ways for stitching the foreground, from 3rd order calibration to ignoring 2 out of 4 cameras. When many actions are happening in different angles, you may even render all cameras separately, without any blending, to comp over your background later. Foreground stitching is mostly used for comping purposes. Fixing people or objects that are closer to the camera rarely renders a good stitch for the background.

Following the background approach, prioritize your foreground stitch based on where people are standing and moving in your shot. Select a frame where the person is standing or walking relatively close to the camera. In the advanced settings of the control points editor, select Optimize Distortion to 3nd Order.



After changing the settings, remove all control points on the background from each set of images. Auto-detect control points on the foreground objects or subjects and Quick optimize. Auto-detect more points on the foreground. Quick Optimize again. When your RMS value is lower than 4, check the clean “bad points” from the steps tab and perform a full optimization.

The background will break, as the distortion was adjusted to stitch your foreground. Save your stitch template and add a version number. Preview with AVP and fix this template until satisfied. Render your foreground work. You may need to render in sections with a stitch template per section fixed. Bring the background and foreground renders into AE to perform **AE Comping**. Done!



PROTIP: By moving **Masking Markers**, you may be able to move visible seams away from the close object or subject, without the need to change your optimizer settings or your control points on the background.

Optimization Settings

Problem:

Optimizing quick, advanced and too much.

The optimizer engine of Autopano is by default really smart as it's what quickly stitches your panorama for an initial auto calibration. The problem solved by the optimizer can be seen as a curve fitting problem: given a curve model (e.g. y=a*X+b) find the parameters (a and b) that make the curve fit at best to a series of data points. In the context of panorama stitching, the model is the equation of projection of a 3D scene point to a 2D picture pixel and the parameters are the calibration unknowns and the orientation of each image.

The optimization settings you may decide to adjust will then affect the stitch quality, its seams, as well as the RMS value. Often, we think optimizing will solve our problem when in fact it can create additional problems.

Solution:

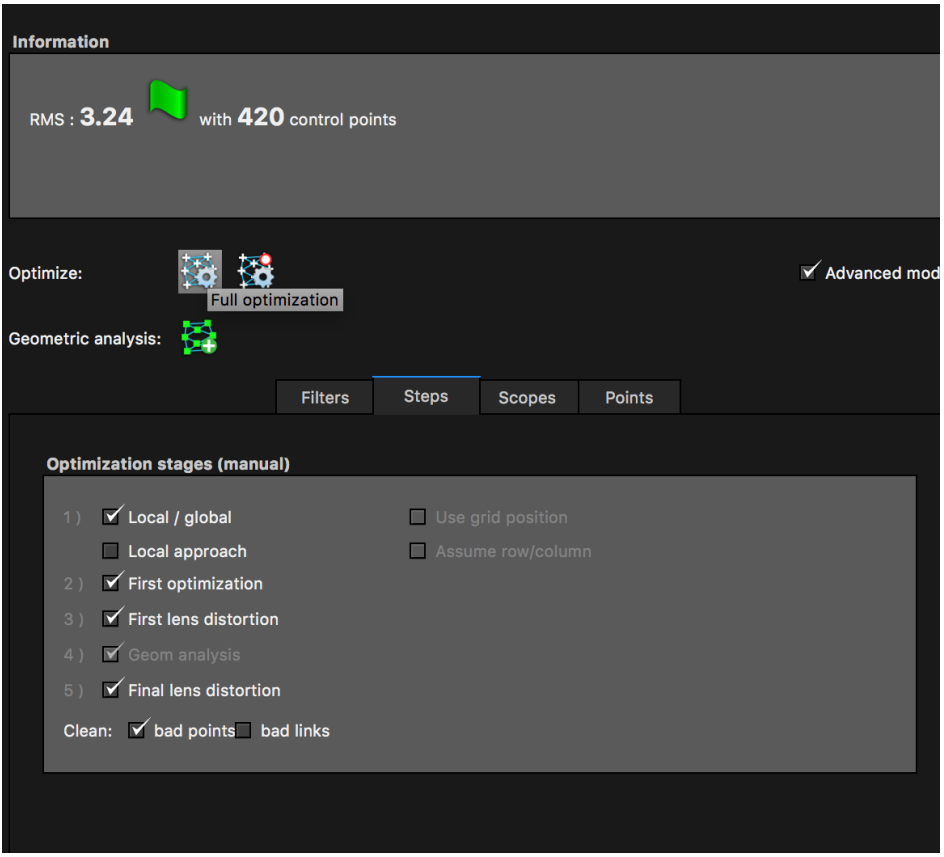
The RMS Value.

RMS stands for Root Mean Square which in statistics is the square root mean of the squares of a sample - oh yee! In our context, RMS is a characteristic of a continuously varying function. Think of the RMS as a value representing the overall quality of the calculations between all control points found in the overlapping area of two images.

The lower your RMS value is, the better your stitch should be!

For the optimizer to calculate the RMS while improving your stitch, it needs a curve model and the data, the matched control points coming from the detector. Some points are good points but never perfectly accurate, while some are completely wrong.

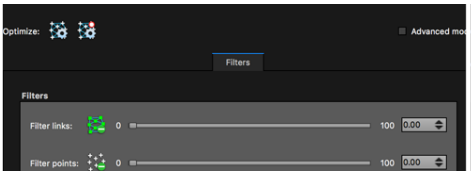
The optimizer will then perform a series of steps to first fit at best all control points, add a threshold for cleaning bad points, re-estimating the model parameters and then computing the final RMS calculation. The final RMS value is the mean size of these error segments, but it is not the quality of the visually stitched panorama.

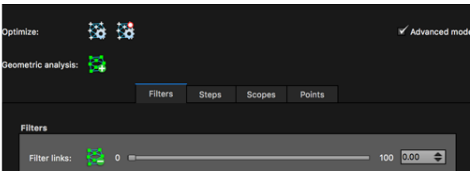


Optimization for 360 Rigs.

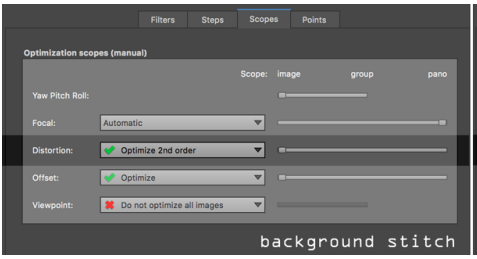
The optimizer's job is to find two main parameters which are the position of each image (yaw, pitch, roll) and the calibration of their focal length, lens distortion coefficients and centering of the optical axis.

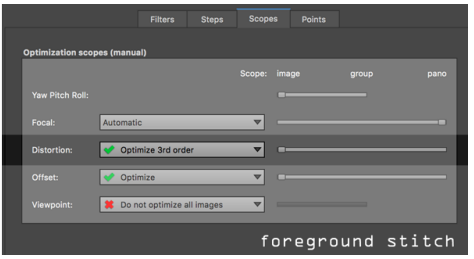
Let's imagine you have a 360 rig with 4 GoPros, and dragged all the videos into AVP. Under the Control Points tab, check Advanced to see all Optimization settings affecting your control points.



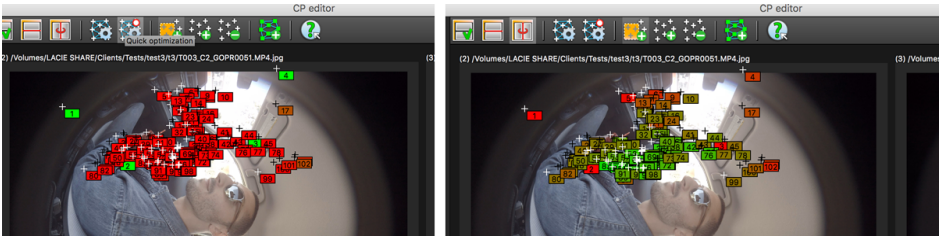


First under Scopes, set both Distortion and Offset to "Images" scope but keep Focal to "Pano" scope as all focal lengths are identical for all cameras. For a background stitching approach, set Distortion to Optimize 2nd Order from the dropdown and 3rd order for foreground stitching.





When stitching, follow a mechanical optimization process. First, detect or add/remove control points a few times before selecting "Quick Optimize". Repeat this step after finding enough control points. When satisfied, check clean "bad points" in order to fully optimize and move to the next pair of images.



Too Much Optimization.

One misconception is with the word “Optimizing”, hoping the engine will visually improve your stitch, when it fact it can make it worse.

When cleaning bad points too much, you will end up removing points which may have been bad but helped balance the equation making the stitch visually better despite the RMS value.

Control Points

Problem:

The control points editor has manual and auto-detection. Which should you use and how will the RMS be affected?

You may be overwhelmed when launching the control points editor, especially if you are stitching with more than 10 cameras. Control points, links, RMS, what does all of this mean? Understand that in order to stitch multiple videos or images together, there needs to have an overlapping area.

Refer to the **Optimization Settings** to understand the RMS value. Videos are stitched or linked together through the use of points that can be added manually or auto-detected. The points are then cleaned up with Autopano's optimizer engine. Should you add points manually or auto-detect them?

Solutions:

Simple, fast auto-detection of points.

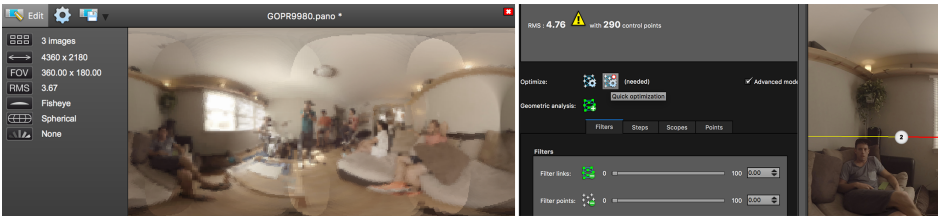
After importing your videos in, AVP will stitch them based on a lens preset or a custom focal length and distortion for your lens. AVP will then do an auto calibration and position the cameras in a 360x180 LatLong format. AVP stitches the cameras together by auto detecting and generating control points, the matching pixels between 2 images.

After the initial calibration, you will then be able to edit the stitch template in APG. Note that APG will auto extract the frame your timeline cursor is on as a JPG for each of the cameras and then operate its stitching process on these images. The changes you make to the panorama of this still

is the template that AVP applies to the rest of the frames of the videos. AVP handles the synchronization of videos and applies the APG stitch calibration of the selected frame to the rest of the video. AVP then spits out the frames of each camera and renders the applied template to the selected in and out region.

The first window of the control points editor will let you adjust the optimization settings and display visualizations of your camera images as a network of links. Each link has its own RMS value.

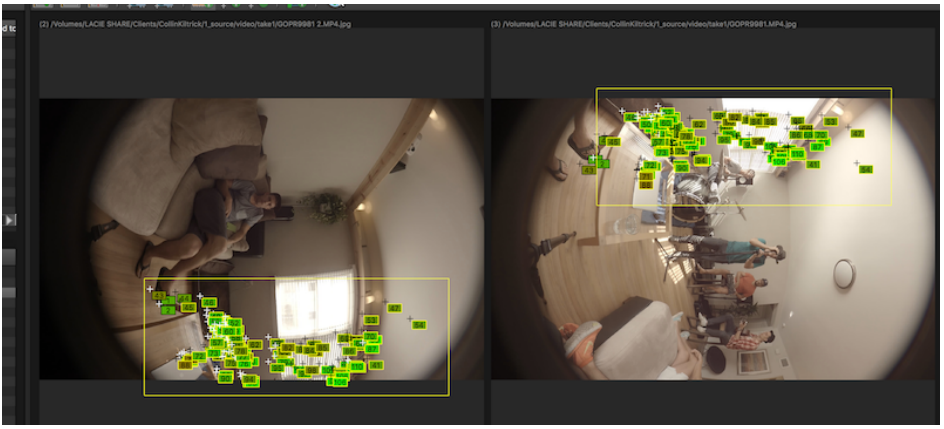
To auto-detect more points, go to the “Cntrl Points Editor” in APG. In the left area, apply a first optimization by clicking on the “Quick Optimize” icon. Check the “Advanced” box to adjust the advanced Optimization Settings. Under Steps, check “Bad Points” and then the Full Optimize icon.



The number in the green boxes is the RMS value for every 2 cameras linked, visually represented with interconnecting yellow lines. RMS is a measure of error between a point and the current estimation, NOT the ground truth which is unknown. Below this number is the number of matching control points between the 2 cameras.

First, edit the control points between the two cameras where there is a clear visible seam. Select the green box linking the two cameras and a window will popup to let you auto-detect or remove points.

In the CP Editor window, you will see the two cameras and the control points connecting them together. Use your mouse cursor to draw a rectangle, selecting the overlap region on one of the frames. Then draw a rectangle selecting the corresponding region on the other frame. APG will automatically detect control points in the shared rectangular area.



Use the Quick Optimize icon at top of the window. Repeat this step as necessary. When satisfied, check clean “Bad Points” and Fully Optimize. The RMS will get updated. Repeat these steps for each relevant link between 2 cameras. Use the PREVIEW area to check the improvements and continue cleaning points in the CP editor until the stitch is improved.

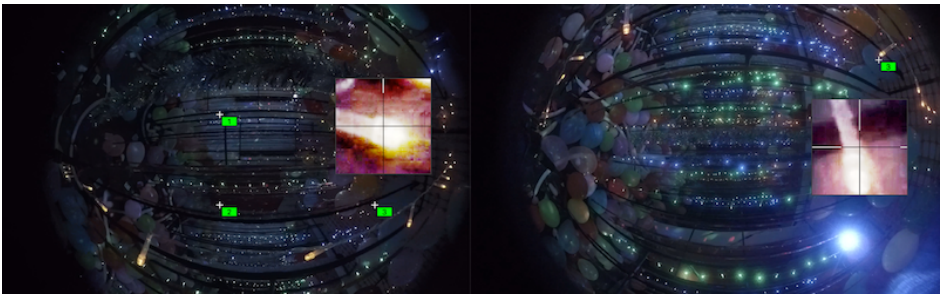
Stitching using only auto detection of control points will be less time consuming and save time to explore other tools, such as the **Masking Markers**. However, you should still understand how to manually add/remove control points.

Manually adding control points.

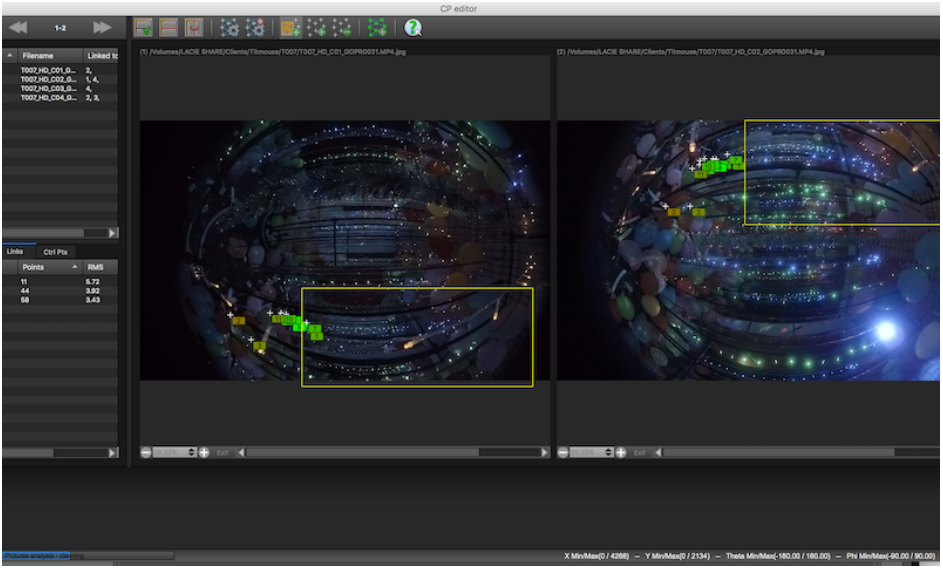
Autopano’s control point detection algorithm is smart but can be mislead by recurring patterns in different angles of a shot.

In this case, Autopano will not understand how to even position the cameras. Position the cameras manually by using the move tool.

After repositioning the cameras, remove all links, and relink at least two cameras to each other by right clicking one and selecting the second camera shown in the dropdown. Open up the second window by clicking on the green box from the two cameras and start by adding control points manually or auto detecting more control points.



In the left area of the window, select another set of two images and draw a rectangle selecting the overlap regions to auto detect and add new control points. This will automatically link two new cameras together. Repeat these steps until all the cameras are linked. Don't forget to optimize the manual adjustments just made.

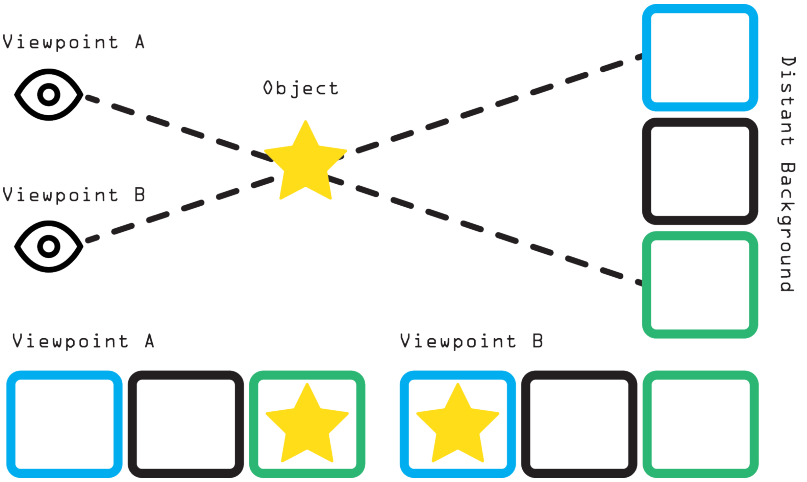


Parallax between Cameras

Problem:

A person or object is moving between two cameras. The subject distorts when crossing the seam even when there is enough overlap.

When you look at an object from two different points of view, nearby objects appear to shift more than distant ones. This is called parallax and is a concept that has been used to measure astronomical distances since 1672.



Two eyes are better than one because they give you two different views of the world. By combining these two views, your brain can estimate distances to nearby objects. Try pointing your finger in front of an object. With your left eye open, align your finger with the reference object in the distant background. Now open your left eye and close the right one. Your finger is not aligned anymore with your reference object. This is the infamous finger experiment to explain parallax. How does this apply to 360 video? How do you control and fix parallax issues in Autopano?

Solutions:

Parallax creates stitching errors but also creates stitching opportunities, fixing overlapping areas where an object needs to be kept or removed using **Masking Markers**, instead of the **Patching Nadir** method. Parallax also creates stitching tricks and advantages such as hiding a monopod in the parallax zone with the **Sandbag** technique.

Blame the 360 rig!

There is no simple solution to the parallax problem. Parallax is currently more a hardware and physics issue and there is no way around it. 360 rigs can't shoot with a perfect entrance pupil because of their construction. The camera sensors will never be from the same nodal center. There's no way to pack multiple cameras with their optical sensors overlapping exactly because of the physical size of the cameras. As a consequence, all cameras in a rig are slightly rotated a distance from the center. Even the slightest distance from each other causes a huge difference. To avoid parallax induced stitching errors, the distance between the optical centers for all neighboring cameras should be the smallest possible. Then the overlapping zones can be stitched cleanly.

Until the perfect spherical camera rig is invented, consider how your subjects are using the space and the distance they can cross between cameras. For now, compromise and adapt your script to save time during post. As the hardware evolves, more experimentation can happen. Warning: don't place the lead actor in between two cameras or your stitcher will end up quitting on you! Avoid creating stitching nightmares so you can focus on the content!

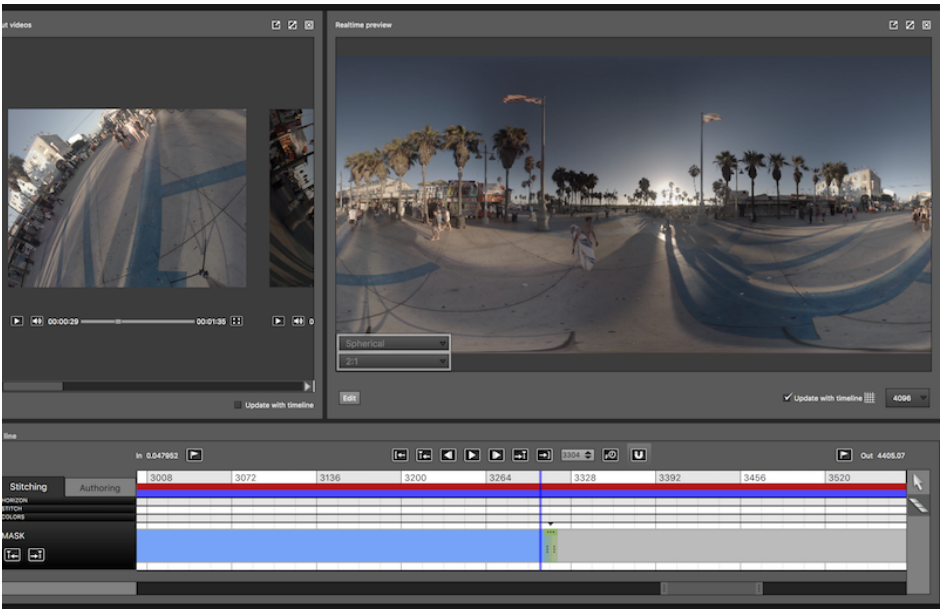
The more cameras in the rig, the less distorted the overlap regions will get. Cylindrical rigs may be used for specific shots, but are a considerable investment in time and money. Stitching time, rendering and disk space are multiplied. **Modified Fisheye** lens are a handy option. Only two cameras modified with a 185 fisheye lenses are needed to fully cover a 360 degree shot.

Switch masks on time!

Something you are probably very familiar with in AE, Premiere or other video softwares is editing masks with keyframing. Use keyframing on masks to fix issues from a subject crossing a seamline.

In AVP, play back the subject crossing from one camera to the next and find the exact frame before the seam is visible.

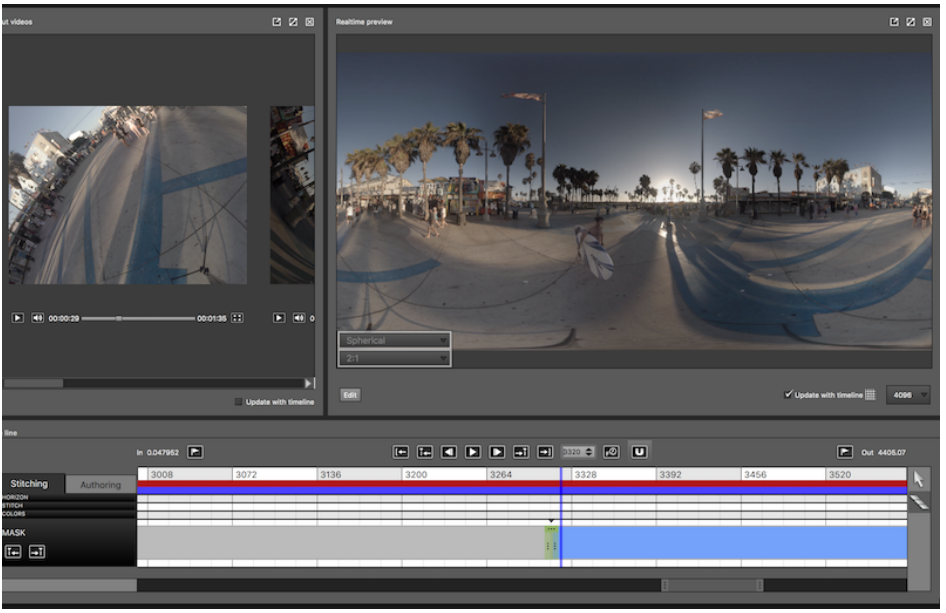
To the right of the timelines are your cursors, one arrow and one razor icon. The razor icon is the cutting cursor. Use the cutting cursor to create a keyframe or cut in the “Mask” timeline at the exact frame you selected. Make sure your cursor is in the section where State is highlighted and select Edit.



In APG, select a green “keep” marker under masking markers. What do you want the marker to keep? The person’s body? From which camera? Do you have enough overlap? Add a keep marker on the camera that contains most of the person’s body before it crosses. Click on the small preview icon, at the bottom left of the panorama, to use the seam’s visualization.

Position the marker at the right place. The less amount of markers, the better.

Head back to AVP and select a frame a few frames after the previous one, then click Edit again.

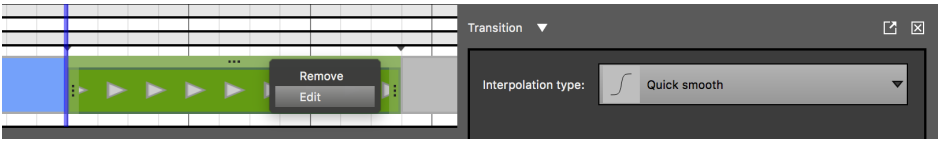


In APG, repeat the previous actions but add a “keep” marker on the other camera. Remove the previously placed marker. Don’t forget to always apply your changes with the green check icon, and save your stitch template for each edited keyframe.

Preview the masking marker changes in AVP. The masks should have solved the parallax issue of the subject crossing between one camera to the other.

This technique works in many cases but not all. You will experience some strange popping in the background, which is the consequence of forcing the blending with markers. The transition will be a straight cut in the timeline. The popping can be reduced by moving the keyframe to the right frame on your timeline. Finding the right timing is key for this technique.

PROTIP: You may be able to smooth the popping by extending your transition from state 1 to state 2 and by adding one of the curve transitions.



For cases where the subject crossed between cameras at too close a distance, the masking markers may not help and the popping will be too obvious. The parallax is even more obvious when the subject is close to the rig and crosses between two cameras. The chromatic aberration towards the edges of the lens is also greater, so try to keep the subjects in **Safety Zones** and stay within a camera view.

One Seam Leads to Another

"Every living being is an engine geared to the wheelwork of the universe. Though seemingly affected only by its immediate surrounding, the sphere of external influence extends to infinite distance."

- Nikola Tesla, How Cosmic Forces Shape Our Destinies

Problem:

As you are fixing a seam, one or two other seams start to appear.

You only have one small seam to fix before rendering. You make some quick changes, almost done! You preview just a few seconds and one or two seams just showed up out of nowhere. Should you have even fixed the small seam in the first place or should you have previewed the entire video before fixing any seams?

Solutions:

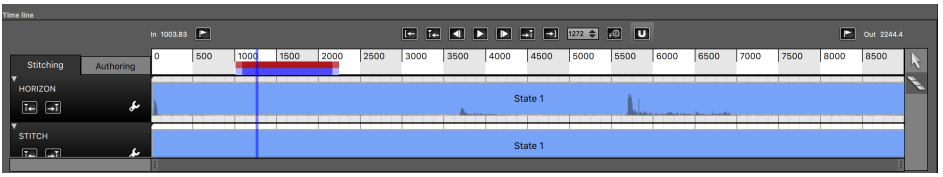
Gotta get them all at once!

To quickly fix all the seams, find most of them in one frame.

The best playback for testing is Quicktime or VLC. AVP is great for previewing but not optimal for real time playback at the actual FPS. This will cause you to miss some seams. Take notes of the frames where seams require some work while viewing your **Dailies Quickstitch**.

When you are ready to fine stitch, reopen your previous kava project or start a new one by dragging your videos into AVP. Select the frame with the most amount of seams and start by fixing all the seams in the frame. Update AVP by saving the template in APG.

Using the blue range selector in AVP will improve the average quality of the stitch for the selected range, based on your in and out points. The Optimizer engine and stitching algorithm will focus on that range, instead of the beginning where your DP's face is all over each camera, unstitchable!



Fixing all the seams at once makes it easier to prevent new seams to show up because you already have an overview of all the worst seams. Make a plan of attack that conquers all the large seams at once. Then the small seams can be fixed with **Masking Markers** or a simple optimization.

Focus on the creative!

Most seams are difficult to fix when there are subjects or moving objects in the scene. Plan and storyboard ahead. Lack of pre-production effort causes many seams and issues in post. Choosing the wrong rig, not carefully planning the movements of your subjects, handling lighting like a traditional film production, barely rehearsing the scenes, etc. An ounce of prevention is worth a pound of cure, you know it.

If you have completely unfixable seams, you may have to reshoot some scenes. If there is no time or budget for a reshoot, then unfortunately the scene will have to be cut. If you have the budget for post, the shots can potentially be saved by applying some post production magic.

If you are in an uncontrolled environment such as a live event, there may be 20-30 people walking in and out of seams. Stitch the static background first for these shots with multiple subjects in multiple seams. Then optimize the stitch on the main subjects in motion. Once there is the least amount of scenes possible, start brainstorming a creative solution.

Try **Rotoscoping** or **AE Comping** techniques to fix the seams. If possible, have the shot cut altogether or look into alternatives such as rewriting the script or selecting a different shot that enhances the story.

Surreal Bodies

Problem:

When a subject is close between two cameras you see strange shapes suddenly appearing.

Unless you are trying to create a surreal dreamscape scene with unconscious bodies, most of the time you will want the stitch to be closest to reality. While the unexpected is always a beautiful mystery, you are looking for a logical solution to this odd problem.

Solutions:

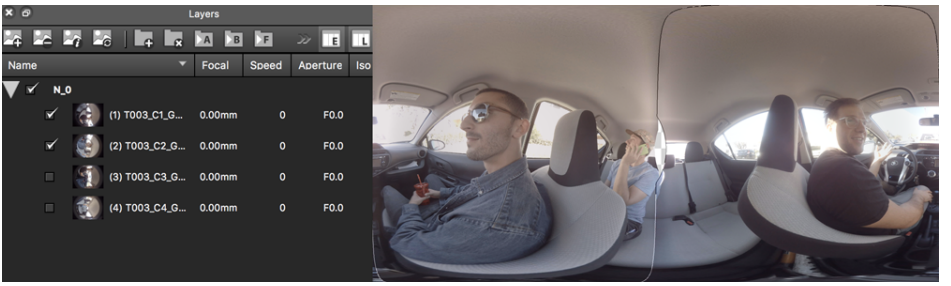
Foreground by subtracting layers.

With **Modified Fisheye** lenses, subjects can get closer to the cameras because the FOV of each camera is wide. The subject will be able to get as close as 1 feet to the camera without breaking a seamline. There is also more overlap between each camera, allowing you to move the seams with masking markers. With the extra overlap, there is always more than enough information for you to fill in or fix pixels. The 4 camera rig with modified fisheye lens almost creates a full 360 video with just two of the cameras, giving you two extra cameras of information. When subjects get too close, you can uncheck either the odd or even cameras (layers 1 and 3, or 2 and 4).

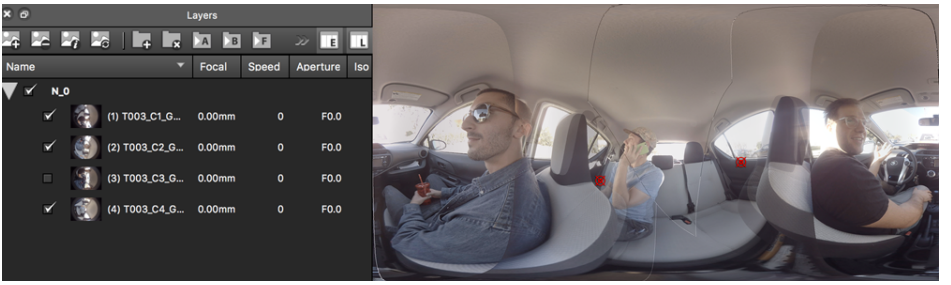
There are many advantages with using a fisheye lens, such as wider FOV. However, there will be higher distortion when a subject moves closer towards the camera. When subjects move between seams, there will also be more parallax because there is more chromatic aberration towards the

edge of fisheye lens. This will create a more obvious popping effect when using the **Masking Markers**.

Check and uncheck some of your cameras in APG by using the group layers at the bottom of the window. When shooting with 185 fisheye lens, there should still be a full seamless stitch even if you hide two of the cameras. This is similar to the iZugar Z2X rig, a 2 camera rig with modified fisheye lens. With 4 cameras, there is plenty of extra pixel information for patching or replacing any problem areas.



Render the best stitch of the two cameras. The panorama may be perfect, or close to perfect with just some missing pixels in the overlap. AVP fills the holes with black. To fill the holes, use the information from the other two cameras. Select the camera layers of the other hidden cameras. Use the red ‘remove’ markers to delete extra information you already have.



Template Stitch

"However vast the darkness, we must supply our own light."

- Stanley Kubrick, 1968 Playboy Interview

Problem:

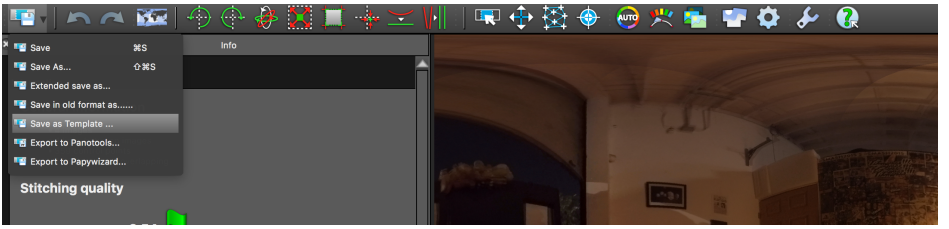
Your footage is too dark and Autopano can't detect any control points.

Autopano has a difficult time generating an automatic stitch when all the pixels are the same. For example, if you shot underwater or in a room with all white walls, most of the cameras will be blue or white. If the shot was underexposed, most of the pixels will be dark and muddy. Autopano's detection algorithm will then have a tough time connecting links and creating a calibration.

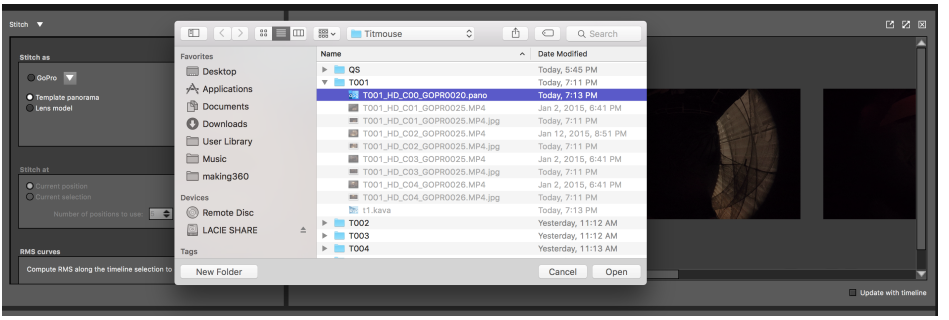
Solutions:

Apply a template.

When stitching videos that are filled with mostly the same color, Autopano will generate a distorted stitch. Some of the cameras may detect control points, while others may twist and warp in the wrong way. The auto detection might overlay images on top of each other, treating the similar colors as control points. You know the exact rig you shot with, so apply a template from a different shot.



Before applying a template, select a smaller range on the AVP timeline for the auto calibration. Look for a section where there are more objects and colors for Autopano to detect control points. If the stitch does not improve, then choose a previous template from another scene that was shot with the same rig and camera configurations.

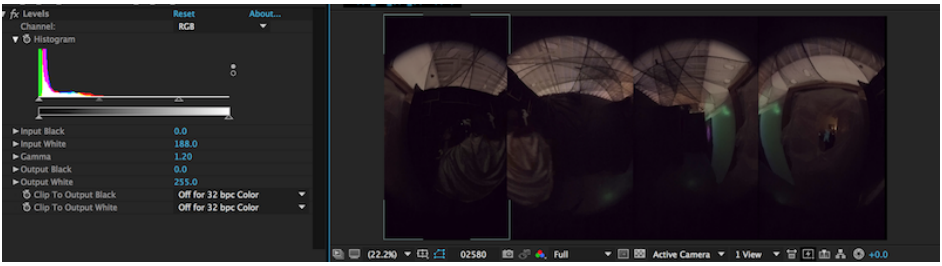


After applying the template, you should see your videos stitched into a nice panorama. However, there will be no control points or links. Under the control points tab, select Geometry Analysis. APG may detect some color points now that you have at least applied the warping and underlying geometry of the camera rig. Remember to optimize any new points found.

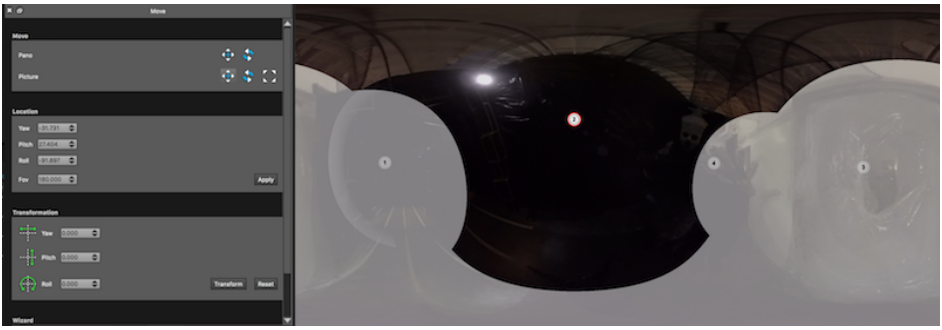
One step at a time.

The optimal workflow for stitching 360 videos is ingest > synchronization > render synced clips > color match > render balanced clips > stitch. This pipeline requires a lot of render time that can really add up. Also, when problems arise, it may be unclear which step of the way the error occurred. Take a deep breath and slow down. Then go through each process step by step to find and confirm where the problem was caused. Check every piece of software and review before rendering again. Test each render that comes out of a program and take meticulous notes.

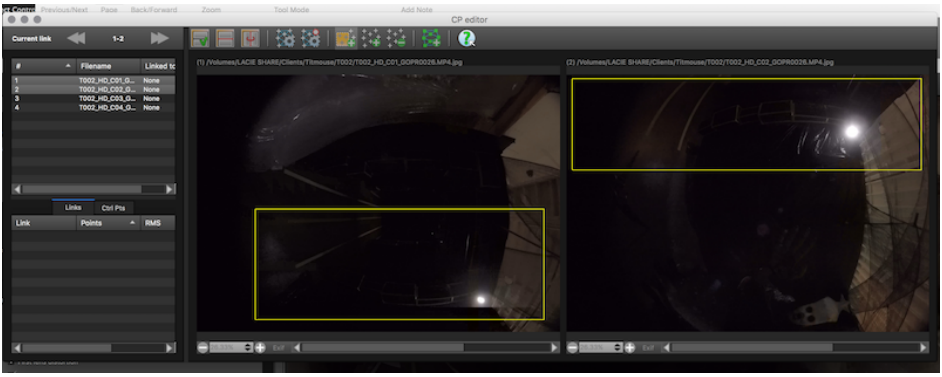
Color Matching all the cameras will improve auto detection of control points. The anti-ghost algorithm won't focus on the unbalanced color issues, improving the **Masking Markers**.



When using templates for stitching, positioning your cameras will also affect the detection algorithm. Check the links for any cameras that were linked incorrectly. Unlink all the cameras and use the move tool > move by camera and place each individual camera into the correct position.



To link one camera to another, use the Geometry Analysis or right click on the number. In the CP Editor, detect and add new control points by drawing a rectangle over the overlapping regions. Add one matching control point at a time manually with the add points tool. Switch to another pair of cameras by selecting two cameras from the list and find new control points to link them. You are right on track again for creating a great stitch!



Masking Markers

Problem:

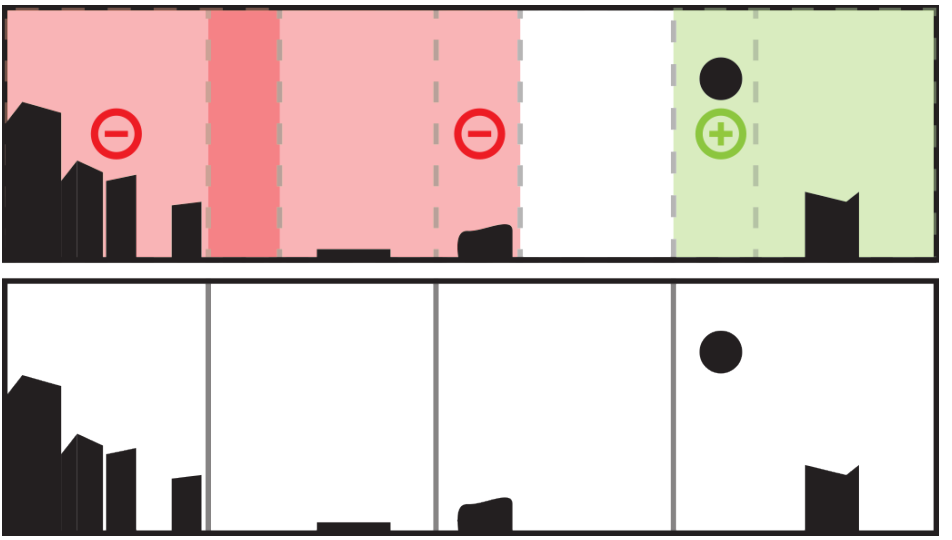
You used the masking tool but after previewing changes, the objects or people are still there.

After becoming familiar with how **Control Points** work, explore the other tools like the masking markers to improve the stitch. Use the red or green markers to either remove or keep an area on a camera.

Solutions:

Understand the anti-ghost.

The masking tool allows you to select where the anti-ghost acts on in an overlap region, deciding which of the two cameras has priority. The masking tool does not create content or pixels. Ghosts can only be eliminated in overlap regions.



Anti-ghost is used in HDR high dynamic range photographs for combining multiple images of the same shot with different exposures. Anti-ghost paints over the areas you want to remove so there are not multiples, such as two or three heads on a person. The remaining images are then composited into one HDR image by the blending algorithm.

The anti-ghost algorithm in Autopano is referred to as “cutting”. This is computed at all times even when you are not using the masking markers. When using the masks, the automatic anti-ghost blending is told which pixels to keep or remove.

Anti-ghost is the smart image cutting algorithm designed to look at the images to avoid blending pixels that do not match. Choosing the placement of a marker is the “smart” part of the algorithm and improves the stitch. APG has a real time visualization of the computation that you can view by clicking the “preview” icon under the Masks panel.

The algorithm analyses the differences between the images and calculates the best cutting path. Anti-ghost will look for a cutting path in areas where the images are alike.

PROTIP: Color match your videos if there are differences in exposure and/or white balance to increase the accuracy of the algorithm.

Smart placement of masks.

Masking markers are most effective when cleaning up the overlap regions and seams. Adding markers in other areas will have no effect except for extending a seam by adding a green keep marker.

Before adding markers, examine and rewatch the clip to understand what is happening in the seam. Then place the markers, keeping the algorithm in mind to achieve the desired effect. There are two overlapping images, one where the subject and his shadow are fully in, the other where the subject and shadow are cut in half. Add a green marker on top of the subject in the first image and a red one on top of the half cut shadow in the second

image. The subject and shadow will be kept in the first image and the half cut shadow will be completely removed.

A common mistake is to use the markers like a brush, covering the entire subject and image with green or red markers. Anti-ghost is a smart, complex algorithm that detects paths in the image. Only a few markers are needed. If the desired effect is not accomplished, try moving the markers to a more relevant place.

Head over to the masks editor.

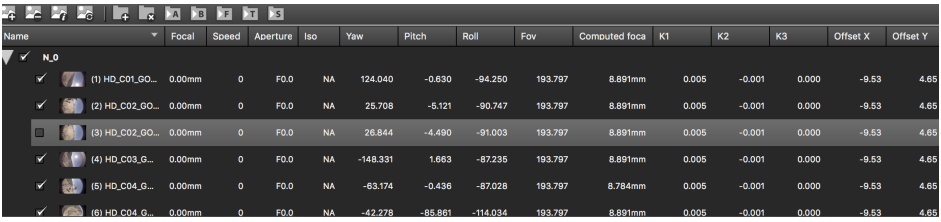
The masking markers can fix visible seams that control points can't. In the masks section, click the small icon that looks like a "Q" icon in the bottom left corner of the stitched image. This helps visualize how the anti-ghost algorithm is moving the seams.

The Masking tool decides which objects to keep (green markers) or to remove (red markers) on the panorama. Masking markers are used for

moving subjects in the panorama.

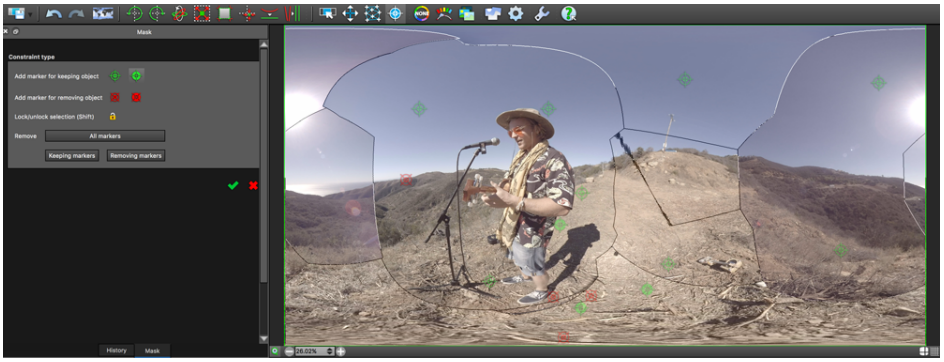
Select the green marker and move the mouse over the object to keep. Make sure the correct camera is highlighted and click. To remove objects, apply the same steps with the red markers.

PROTIP: If your cursor doesn't let you highlight a camera, check or uncheck camera layers.



Name	Focal	Speed	Aperture	Iso	Yaw	Pitch	Roll	Fov	Computed foca	K1	K2	K3	Offset X	Offset Y
N_0														
(1) HD_C01_GO...	0.00mm	0	F0.0	NA	124.040	-0.630	-94.250	193.797	8.891mm	0.005	-0.001	0.000	-9.53	4.65
(2) HD_C02_GO...	0.00mm	0	F0.0	NA	25.708	-5.121	-90.747	193.797	8.891mm	0.005	-0.001	0.000	-9.53	4.65
(3) HD_C02_GO...	0.00mm	0	F0.0	NA	26.844	-4.490	-91.003	193.797	8.891mm	0.005	-0.001	0.000	-9.53	4.65
(4) HD_C03_G...	0.00mm	0	F0.0	NA	-148.331	1.663	-87.235	193.797	8.891mm	0.005	-0.001	0.000	-9.53	4.65
(5) HD_C04_G...	0.00mm	0	F0.0	NA	-63.174	-0.436	-87.028	193.797	8.784mm	0.005	-0.001	0.000	-9.53	4.65
(6) HD_C04_G...	0.00mm	0	F0.0	NA	-42.278	-85.861	-114.034	193.797	8.891mm	0.005	-0.001	0.000	-9.53	4.65

The seams will update in real time according to the smart placements of the masking markers. Click "Preview" and apply or remove markers until the preview looks seamless.



In the “Preview” section, you can also test out the alternative blending options - Smart or ISO cutting. Save your pano file, go to your preview of AVP and play back from the IN Frame to see the improvements made.

Stereoscopic 3D 360

Problem:

Stitching in stereo mode, similar workflow squared.

You decided to shoot your scene stereo either on an 8, 12 or maybe 14 camera rig. It will definitely impress viewers by adding depth to your 360 videos, maybe even compete with some computer generated experiences! Stereo 360 video experiences however, lose half of the potential resolution as you will need to render your left eye monoscopic video on top of your right eye monoscopic video, thus creating an Over Under, generally 2300 x 2300, for playback in a VR headset. You know how to stitch a mono panorama, but how do you approach stereo stitching with two videos? Is it a similar workflow?

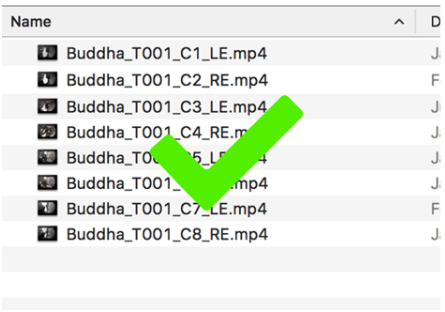
Solution:

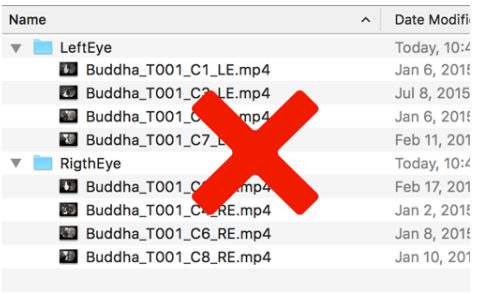
Most of the critical work to create a stunning stereo experience should happen during pre-production and production. When you are filming in stereo, the distance between cameras, their alignments, how subjects were instructed in relation to the space are all things which can't be corrected in post without a tremendous amount of work, doubling and sometimes tripling your original budget. Remember, stereo is not double the work, but exponential. With every adjustment made to one eye, you have to go back to the other eye to check the disparity. While stereo can enhance the experience, done incorrectly, it can create viewing discomfort for the viewer if the stereo does not converge properly.

AVP Stereo Mode.

Autopano has the ability to assign camera files to left or right eye. Therefore, you can stitch and render both left and right monoscopic videos using the same stitch template. Make sure that all your videos are in the same take

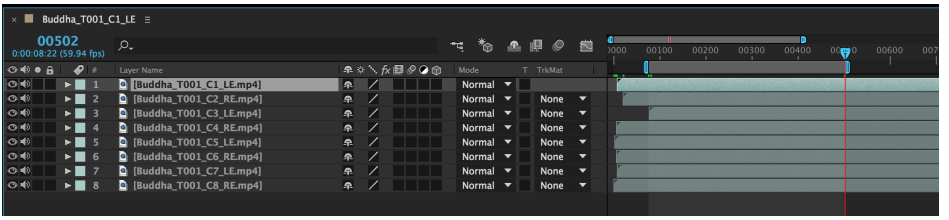
folder and not separated in 2 folders, such as a left eye folder and right eye folder. The stitch template is saved and used for both eyes.





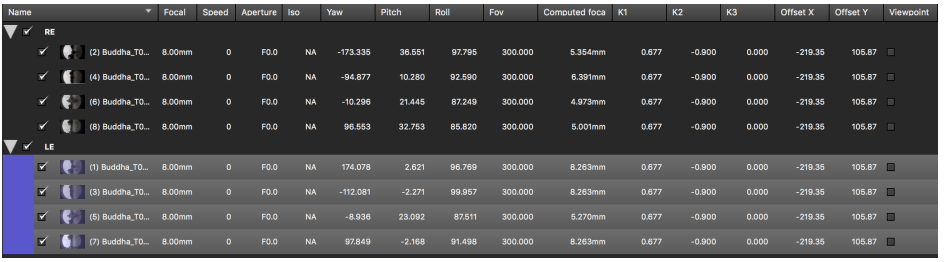
Issues in stereo stitching include the cameras not in being in sync, the color not matching, and subjects being too close or crossing between cameras. These problems will all cause the seams to be very apparent and with subjects too close, the seams may even be unfixable. If your subjects are crossing at a farther distance from the camera, the seams are fixable but the depth isn't as impressive, questioning the need for stereo. Before you even stitch anything, reduce all the risks involved with stitching in stereo. Perform **Synchronization** and **Color Matching** on all your cameras outside of Autopano.

With all your cameras in one take folder, and file names reflecting Left eye (LE) or Right eye (RE) camera, synchronize manually with After Effects. You will be able to sync based on the audio waveforms as well as any flash or motion signal. Trim all the cameras to only have the available footage in all cameras perfectly synced by the frame. At the same time you synchronize the cameras, adjust color matching in the same step. Correct the mid gamma level slightly on just the needed cameras, but never all of them since one is used as reference. Re-export all your cameras as mov lossless files or mp4s.



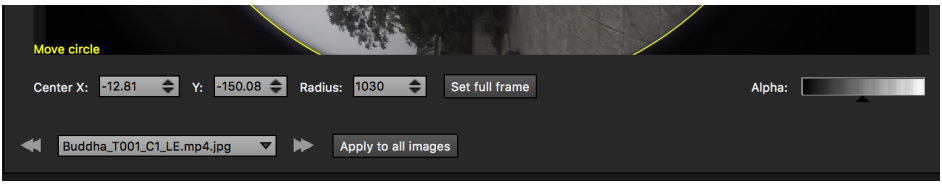
You've reduced the risks of a bad stitch with these two steps. Import your videos to Autopano, with same length, same FPS, same format, synced, and color matched. First, check the stereo tab. Turn on the stereo mode and assign your cameras to whichever eye. This is why renaming your files with LE or RE as prefixes can be handy. Go to your stitch tab, input your lens and focal length. Now you are ready to stitch.

In Autopano, start by creating a new group layer located at the lower area of APG. Then drag all your right eye cameras in the new layer. That way you can easily switch between left and right eye while stitching.

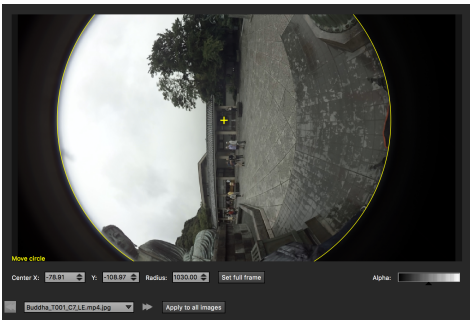


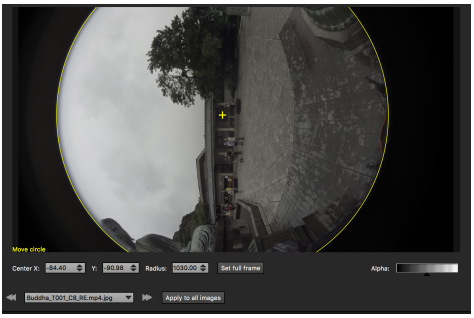
Next step. **Circular Crop Factor**. Handle this tool with caution. When the calibration isn't right, it may be due to your lenses, in particular fisheye

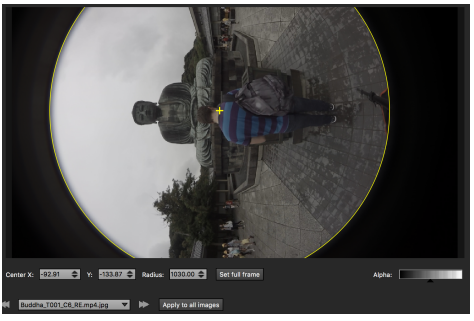
lenses, and not a control points issue. Edit the circular crop of each of your camera by first choosing a radius amount and apply to all images.

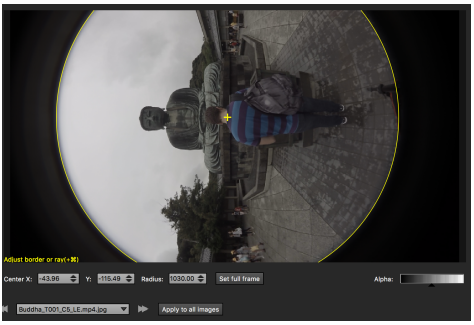


Fix the alignment of each camera by pointing the center point on the exact same pixel for each pair of cameras plus the horizontal offset needed to create depth. A farther object will need the center point placed almost exactly on the same pixel while a closer object will have a greater offset of the center point.







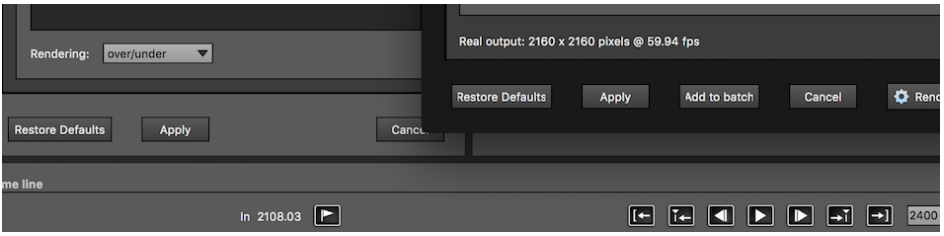


Finally, you are ready to fine stitch. Here's the catch with stereo stitching, it's not double the amount of work but more like squared! Why? Every time you fix a seam, you will need to ensure the seam is fixed the same way on the opposite eye for stereo disparity. If not fixed, you may need to go back

and fix it differently.

An Autopano stitch template holds a great amount of information except when the computer crashes. Remember to save constantly and save all the different versions of your stitch template to easily revert to a preferred stitch version.

Lastly, do some **A/B Testing** of different ways to fix a seam and to prioritize only the actions with the most amount of depth, usually in the foreground. Even as viewer, you may not notice a small seam in the background, but you will be impressed by an amazingly stitched 3D movement coming at you. Render a test with AVP by first selecting Over Under in the Stereo tab. This will allow you to get a 2160x2160 render. If you need a specific over under or side by side, you can use FFmpeg to combine 2 videos after rendering each eye from AVP separately.



Over Under vs Side by Side.

To render specific stereo video outputs, render from Autopano your left and right eye videos separately as mono files. In AVP, click the Stitch tab and select the eye to render only. If both left and right are visible in the preview area, like a bad blending, then you may want to uncheck the group layer containing the videos of the eye you're not rendering. You will then have to switch eyes and render the other.

Once you have both left and right monoscopic panoramic videos, you can either combine them within After Effects or with FFmpeg. Use FFmpeg to save time while testing, and to control compression for final renders. If you're not familiar with this tool, check out the chapter Hello FFmpeg.

The maximum resolution of video a headset like an Oculus Rift can handle is 3840x1920, pushing it to 4096x2048. This means if you are rendering a stereo video, you will need to combine both left and right videos to fit within these dimensions. Some players may handle a larger width and combining side by side would be ideal to keep the same amount of pixels for both eyes. It all depends on the player specs your stereo video will play on.

If you need to combine your videos as an over under, left eye on top of the right eye, here's the one line to enter in your Terminal after changing the filenames to match yours:

```
ffmpeg -i left.mp4 -vf "[in] pad=iw:2*ih [left]; movie=right.mp4 [right];[left][right]
overlay=0:main_h/2 [out]" output.mp4
```

If you need to combine your videos side by side, left eye at left and right eye on the right, here's the one line to enter in your Terminal after changing the filenames to match yours:

```
ffmpeg -i left.mp4 -vf "[in] pad=2*iw:ih [left]; movie=right.mp4 [right];[left][right]
overlay=main_w/2:0 [out]" output.mp4
```

Circular Crop Factor

Problem:

The circumference of your fisheye lens is leaving some blurry traces in the overall blending.

A fisheye lens is designed for shooting ultra wide angles, usually 180 degrees or more. The images produced are highly distorted, giving a dynamic or abstract feel. There are two types of fisheye lens, circular and full-frame. Using a circular fisheye lens results in a circular image with black edges along the frame.

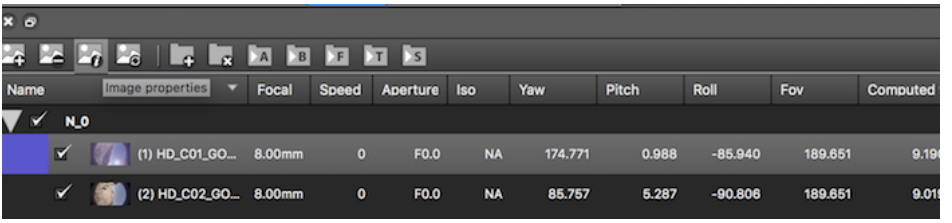
Photographers play with the ultra wide angle effect experimenting with artistic distortion. For 360 video, fisheye lenses valuable to the engineering of the rig, improving the results of the footage. Each individual camera has a wider field of view, increasing the overlap area between cameras. Less cameras are then needed to complete a full 360 degree stitch, so the cameras can be spaced closer to each other, reducing parallax. Keep in mind the final output resolution of the panorama may decrease with the extra overlap.

If you want to shoot with subjects extremely close to the camera, fisheye lenses are the way to go. However, fisheye lenses produce fuzzy edges around the image circle and capture traces of lens flares or blueish light around the image. Autopano blends some of these artifacts as well as the black frame into the stitch sometimes. You may see black or blue blobs in the blending of the sky or ground.

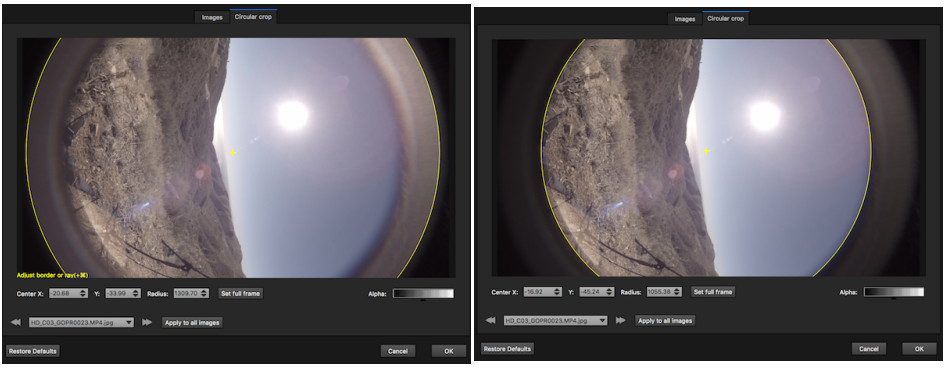
Solution:

Crop it like it’s hot

When stitching footage shot with fisheye lens, check the Circular Crop tab and set the image properties. After an initial calibration, open the stitch in APG. Look for the tool with an image icon and small info “i”. Click for the popup.



Autopano will then show the frame extracted for the stitching calibration of each camera. Edit the circular crop area, leaving the black and fuzzy blue out. Crop only the crisp and clean image area by decreasing the diameter of the circle. Go through each camera one at a time.



As you can see, every single lens is different, even when they are the same make and model. Their centers will be just pixels off in the frame. Autopano will update the blending and the black will not be included in the anti ghost blending algorithm. The black and blue blobs should now disappear. Use the **Masking Markers** to fine tune if there are still traces.

First Person

Problem:

You need to stitch a first person POV mode.

The best first person POVs can be experienced through few proven programs such as combat training for the military, flight simulations for the Air Force, virtual driving simulations for tank drivers and firemen, surgery simulations for medical personnel, etc...

First person experiences are truly powerful and will contribute to the future success of VR. Why recreate reality if you could make your audience dream on demand? or put themselves in the middle of an adrenaline inducing heist? in surreal landscapes? What if our schools taught history by recreating the past in VR? or science by submerging into microscopic worlds? Virtual Reality lets you make the impossible possible. "The only limit is your imagination"...and the treatment of looking down.

Solution:

The Treatment of Down.

Should you have a body in a first person experience? VR makers are all struggling with the concept of looking "down" in a 360 video. In VR games, this is less problematic since you can model a body and script interactions with a body and arms in a game engine like Unity or Unreal Engine. In VR, disembodiment is one of the reasons viewers get the motion sickness you may have heard of or personally experienced. If you are considering making a first person experience, what can you possibly display where your viewers are looking down?

Less is More

As explained in **Patching Nadir**, replacing your equipment or tripod by clone-stamping patterns in order to recreate a floor provides a great result, without distraction from the content. For **Moving Shots**, **Shoot the Moon** at the exact same speed as the recorded motion. For stereo experiences, shoot your plate in stereo, or the transition from stereo to mono floor may disturb your viewers, taking the focus away from your content. You can think of the tripod or nadir hole as a limit of technology or instead as a creative challenge! Think of unusual ways to treat the problem. For example, a way to embody your viewer in another body without anything when looking down, could be to composite a plate of your actor facing a mirror as an intro shot.

Offset the Camera

The “selfie” generation is gonna love this one! Take your stick out (wink) or over a bridge and all your fans, scared of looking down, will be forced to look at you. The use of a monopod or selfie stick works especially for showing different world perspectives or impossible viewpoints. Both the bottom and top of your 360 recording are included. However, you may encounter problems removing the stick which will show in front of its holder. This technique is highly recommended for a third person experience.

Logos are Lame, Art is Cooler

No logo will bring any interest to your 360 piece. At the least, don't use the simple black circle with logo centered in it. Try embedding your logo creatively. The logo is a great quick way to hide the tripod but try designing interesting graphic art to hide the tripod. Some have tried the mirror effect, gradient to black, distorting...

Camera in the Air
Hanging the camera on a wire or fishing line results in very natural camera viewpoint and eases the stitching process. Drone and Helicopter viewpoints are also very captivating, and interestingly, you can easily mask the sky. In many cases, this is ideal. However, you will need multiple wires to help stabilize the camera and enough time to prep this type of set.

Pre-rendered 3D Model
Try compositing a 3D body model on top of your rendered live action 360 video. One of the best examples is from the Insurgent VR experience by Kite Lightning. This approach seems pretty complex to achieve but with the use of Andrew Hazelden's Domemaster3D in Maya or Blender's built-in LatLong renderer, any artist can create a custom model or buy a 3D model and render it out to LatLong mono or stereo and comp it in AE later.

Head Mounted Cameras

Experiment placing and stabilizing the 360 rig on a chair with the subject's head leaning backward or sideways if body was laying on a floor or table. In these cases, stitching can get tricky but you will see the actual body of the subject to embody.

Foreground Stitching.

First you should find the frame with the most amount of body parts in the foreground, even if the arms are just static on a chair. Edit the frame using a foreground approach.

Looking at the seams and the control points already detected, start by cleaning bad points and then remove all points off the background. Once you have removed the points on the background, find new points on the body parts for each pair of camera.

Click on the Optimize button when the clean up of the control points has been done. To improve the stitch as it probably won't be fixed, should adjust the optimization of the lens distortion since you are stitching a complex parallax problem. The sensor of the cameras is not perfectly aligned/centered with the lens and because of that each camera has its own lens distortion model.

Under the advanced optimization settings, at Scopes, try setting Distortion to Optimize 3rd order and scope to Image. Then Optimize. The stitching should be much better. Recreate the leftovers from bad blending, frame by frame, with **AE Comping** or **Rotoscoping** techniques, to attain perfection.

The Mirror Trick.

It is possible to trick your viewer's eye by using mirrors and reflections. Imagine yourself in a bathroom looking straigth into a mirror. Without the need to have a body when looking down, your viewer will see another body straight from the reflection.

The effect is a great hack for a simple embodiment. Plan your plates before shooting. You will need to shoot the scene in 360 and then place the rig at the position of your mirror or reflective surface. The actor or actress should be placed where the rig was previously, facing the mirror. The rig is now recording your subject. You will then comp this footage instead of the mirror or reflective area. Don't forget to **Shoot the Moon** to replace the tripod from the nadir area.

Moving Shots

Problem:

You need to stitch a moving or dolly shot.

Unless you are into hyperrealist films with beautiful ultra long takes with minimal camera movement that reveal the spontaneous manifestations of daily life, shooting without any camera movement may be boring and limiting. Most 360 videos place the viewer in a static position and you want to experiment with the fourth dimension, xyz over time.

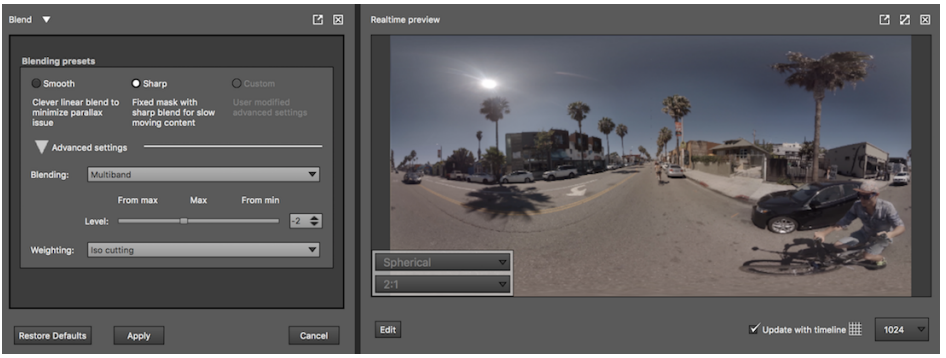
In VR, a dolly shot with even the slightest movement of the camera may trigger instant motion sickness and nausea. This occurs when your vestibular system detects changes in motion and movement through eye input, but your body does not physically move. Imbalance occurs in the inner ear resulting in VR sickness.

Until research and development for galvanic vestibular systems for virtual reality improve, it is up to game developers, content creators, and filmmakers to make the best decisions and choices to reduce motion sickness. Whether shooting a moving shot on a dolly or drone, make sure to engineer proper rigging and equipment for **Stabilization**.

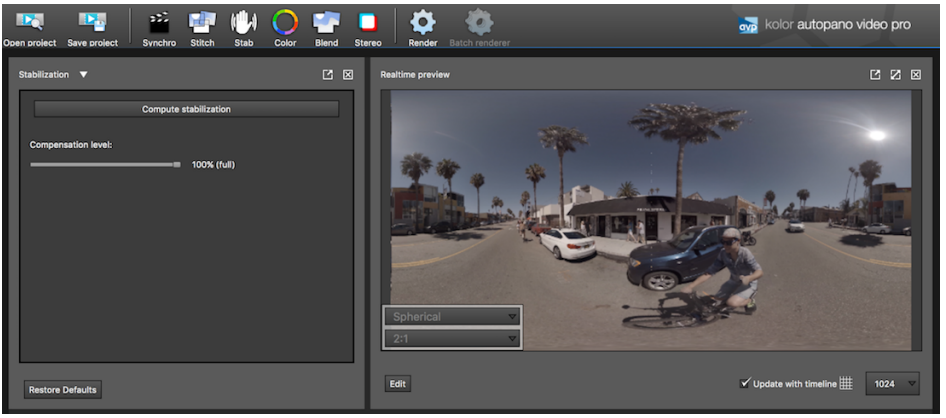
When stitching your moving shot, the seams are more visible from motion.

Solution:

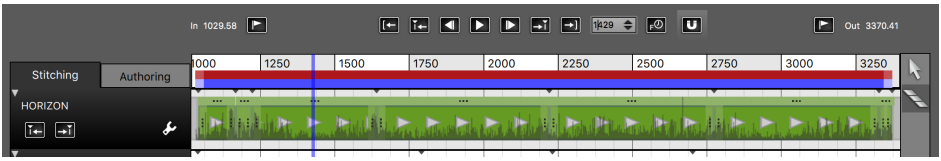
After synchronizing and color matching your cameras, start by setting the blending in your Autopano project to ISO. Smart cutting disables certain tool analyses to stitch a moving shot.

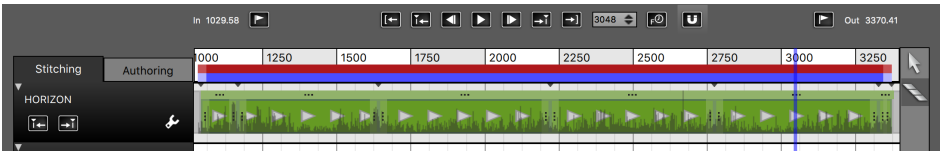


First stabilize the shot. Autopano has a built in motion stabilization tool that can be applied to any moving shot. The motion stabilization tool may take awhile to process the entire shot, so select only the in/out range you want based on your **First Assembly**. Make yourself a cocktail while you wait. Cheers!

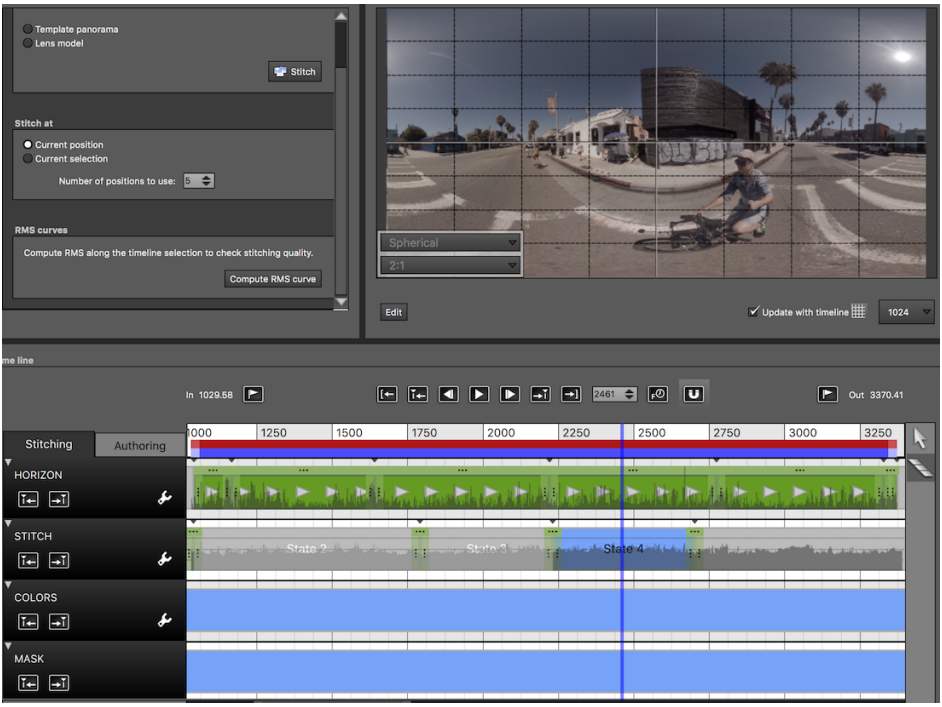


Second, fix the horizon. The stabilization will help smooth the shaking but will lose the horizon. Correct the horizon after performing the motion analysis. Use the cutting cursor to edit the horizon, from your IN point to your OUT point. Then apply your horizon changes section by section.





The third step is running RMS Analysis. Whether you used a head mounted camera rig, monopod, or expensive motorized dolly, always use the RMS analysis on any type of moving shot. Click RMS, located to the left of Stitch in the AVP timeline, to start the analysis. Use the cutting cursor to separate the timeline into sections that are similar visually and in terms of RMS. For example, if there is an area where the RMS values are high, cut it into a section. Now re-stitch and optimize each section by selecting its state. Restart the RMS analysis to see the improvements in updated values.



Lastly, try **Patching Nadir** for large dollies that covered the ground floor. Expensive motorized dollies are a great luxury but come with complex compositing work. A plate that was shot at the exact speed, lighting, and camera position is needed to cover the dolly. Otherwise, you may have to track and recreate the floor.

A/B Testing

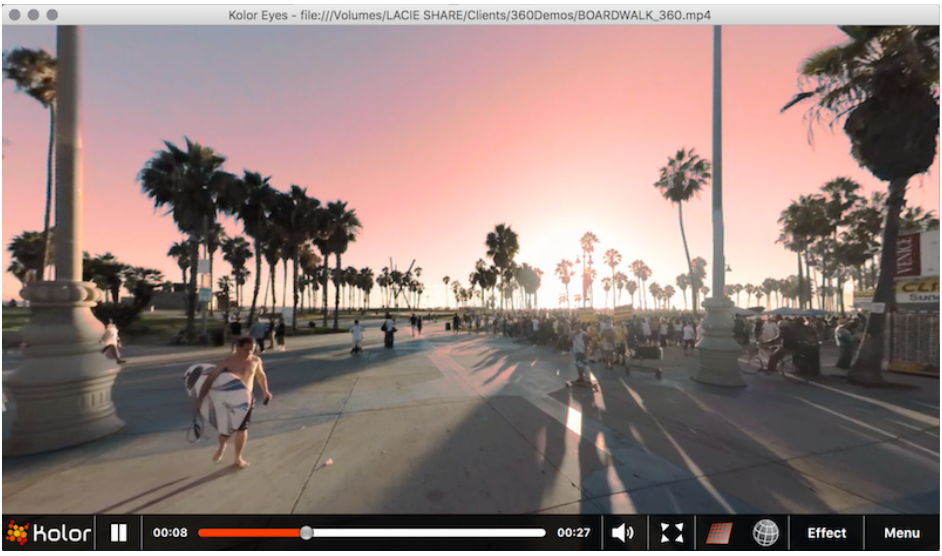
Problem:

You need to compare between renders and decide what improvements are required.

You can render multiple versions of the stitched video in AVP by switching .pano templates or adjusting certain settings, such as ISO or Smart blending. Before rendering your final high quality uncompressed tiff sequence, do an A/B test of the different render choices by viewing them in a headset. Seams and errors are more apparent when viewing through a headset. How do you upload, playback, and compare versions?

Solutions:

Playback on the desktop using Kolor Eyes.

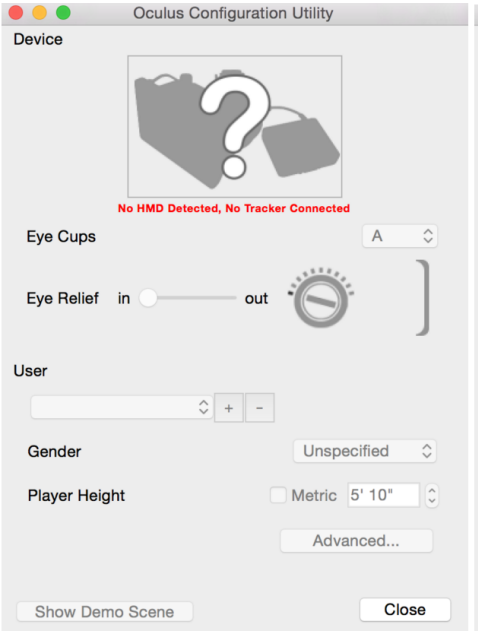


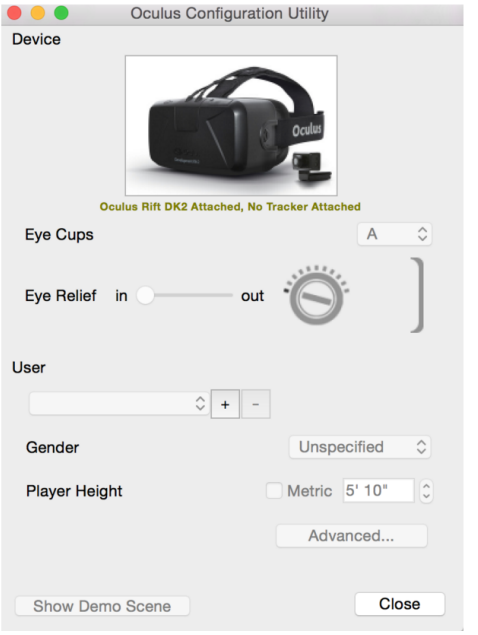
The easiest way to quickly preview your stitch is to drop it into Kolor Eyes player for desktop. Open the application and drag your stitched mp4 or mov into the Kolor Eyes window. Use your mouse cursor to rotate around the panorama, checking for seams and any areas that require clean up.

Kolor eyes to Oculus Rift DK1 or DK2.

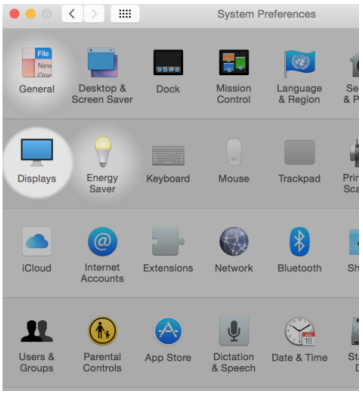
After loading your video into Kolor Eyes, plug your Oculus Rift device into your machine with the HDMI to USB cable.

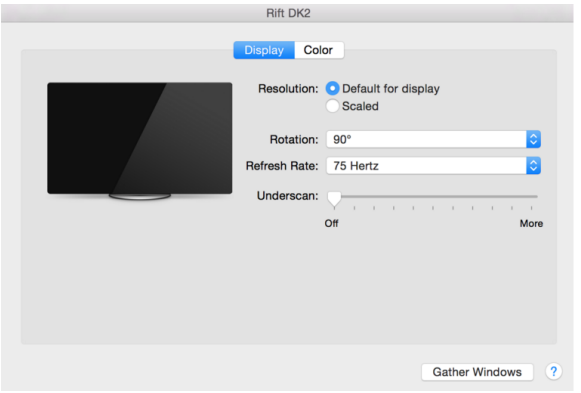
Download Oculus Runtime for Win or Mac. After the installation, go to your Applications folder and open the RiftConfigUtil.app. You should now see the Rift device recognized.



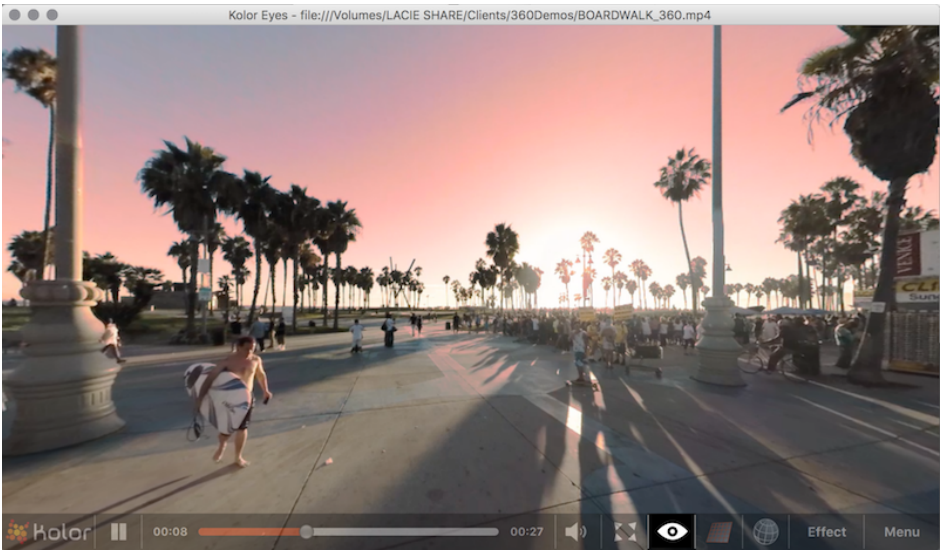


Next, check your Display preferences and make sure to rotate the Rift display by 90 degrees.





Back in Kolor Eyes, you should see the eye or Oculus icon at the bottom of the window. Click on it and check in the Rift to see if your video is showing. The Rift's headtracking sensor should now be controlling the orientation in Kolor Eyes. Put the headset on and check for seams and areas that require additional attention.



Upload to YouTube 360, View with Cardboard.

To preview your stitched panorama, upload your video to YouTube using their temporary **Python script**.

After uploading, go to your video page on YouTube and use your mouse cursor to rotate and check all areas for seams that need more work.

Now that your video is on YouTube, download the YouTube app onto your smartphone. For iPhone users, you can only view the 360 video with your phone and not Google Cardboard, until support between YouTube and iPhone is provided.

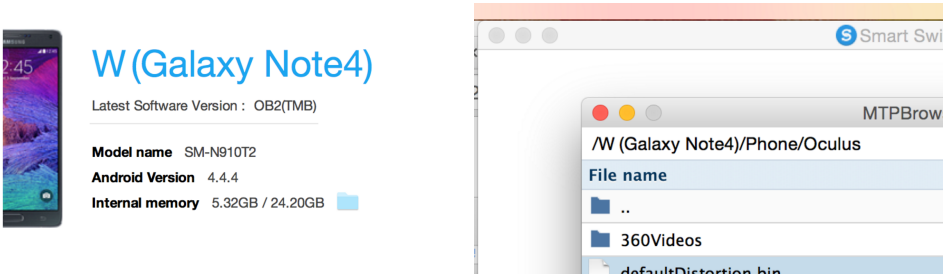
If you own an Android smartphone and have downloaded the YouTube app, go to your uploaded 360 video and press the “cardboard’ icon. Put your smartphone in your cardboard and check for seams that require attention.

Gear VR and Note4 or Galaxy S6.

If you are on a Mac, download **SmartSwitch** to upload files to a Samsung device. Install the application and let it restart your computer.

Start SmartSwitch and click on the dropdown arrow next to the phone name. You will then see a ‘folder’ icon to open your phone’s library. In this directory, go to the "Oculus" folder and create a "360Videos" folder. Drag any of your 360 videos to test into this folder.

PROTIP: For stereoscopic 3D 360 uploads, make sure to add "_TB" for Top / Bottom or Over Under files, and "_LR" for Left / Right or Side by Side files.



Under ‘Apps’, launch the Oculus app and start the 360 Videos app. Put the headset on to review. You can also access the 360 Videos app from the Oculus Home menu.

Tap the touchpad of your Gear VR while pointing the gaze cursor on your video. Then check for the seams that require your attention.

Mise en Place

Problem:

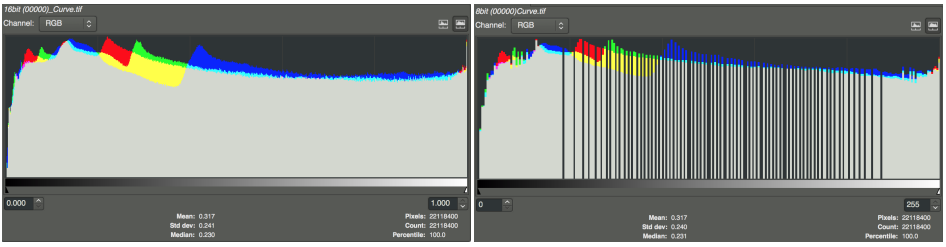
You need to setup your After Effects project after rendering out 16 bit tiff frames uncompressed from AVP.

After rendering your stitched panorama(s), there is still work to be done! You have to hide the tripod, add transitions, effects, color, and titles. Should you work in Premiere or After Effects? Which shortcuts and pre-comp settings are the most optimal?

Solutions:

After Effects 16 bit Project.

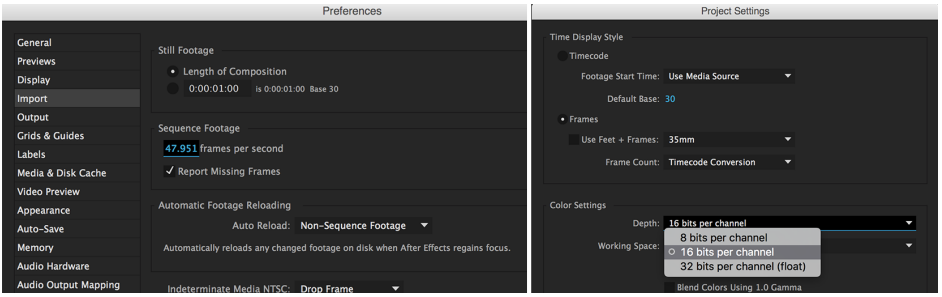
Every step along the pipeline will process and distort your colors, decreasing the potential for the highest quality picture. Your eyes may not be able to see, so look at the changes in unique number of colors and RGB histograms via GIMP. They will be drastically affected depending on your setup and plugins for effects and color grading.



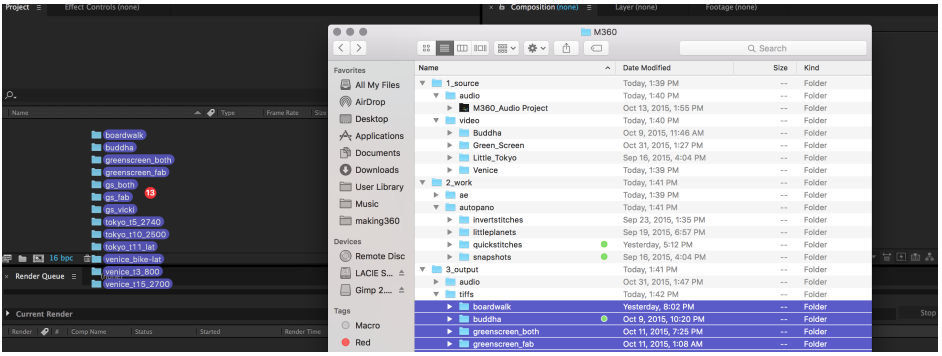
Working with 16 bit tiffs in an 8 bit AE project will reduce the color information by half at render time, increasing the risk of introducing banding. Banding in a VR headset is more visible than any other medium. Unless

you are exploring banding as an effect, setting your preferences of AE the correct way before working on final master files is highly recommended.

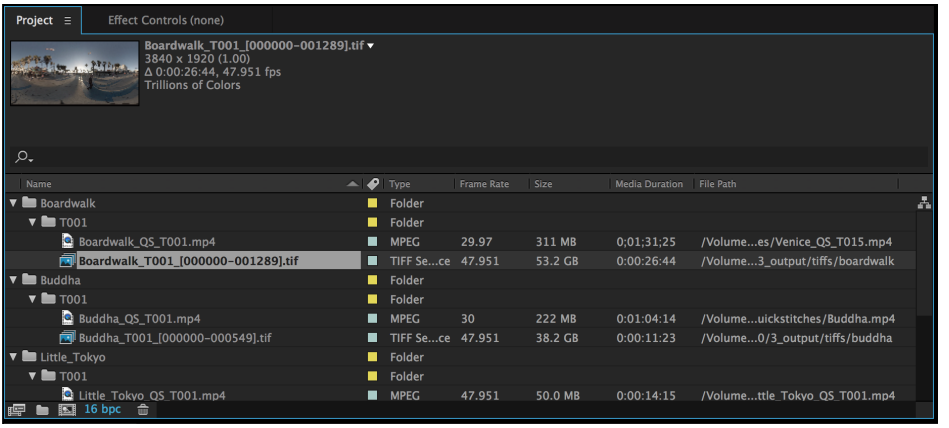
Open AE and locate the Project Settings under File. Set the color bit depth to 16 bits per channel. Then under the Import Preferences, don't forget to change the default frame rate (FPS) to match the frame rate or your source footage. To output a different frame rate, set the desired FPS under your composition settings, and perform a time remap to match that new frame rate.



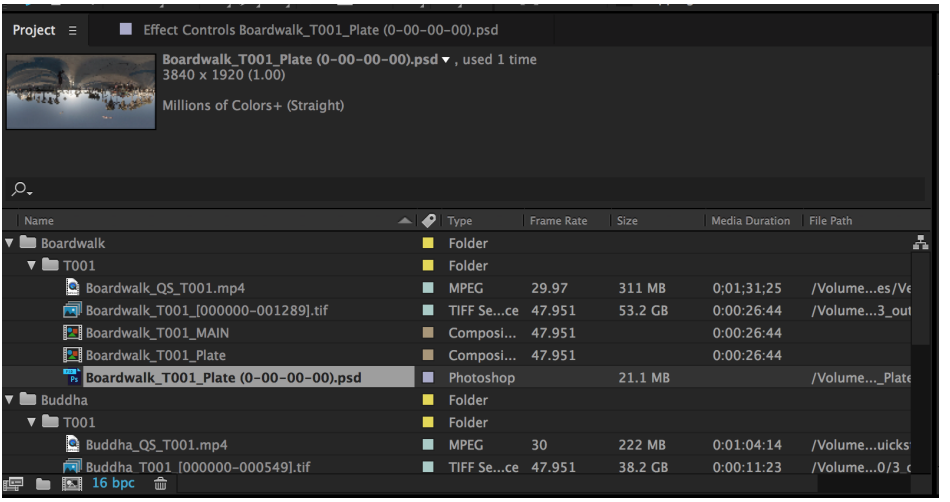
Import the tiff sequences rendered from Autopano and rename them with the scene and take of the sequence. Create folders matching the names of your scenes and place the stitched tiffs into the corresponding folders. Keep the digital workspace clean and comprehensible, implementing a system with your team. Organize every project with folders separating the source files from output files. Add a working folder between any step that includes the work from a specific software. Separate renders from the work folders into the main Render folder.



Organize your AE or Premiere project with scene or take folders that include the stitched mp4 (not final as it is compressed) and the tiff sequence (uncompressed).



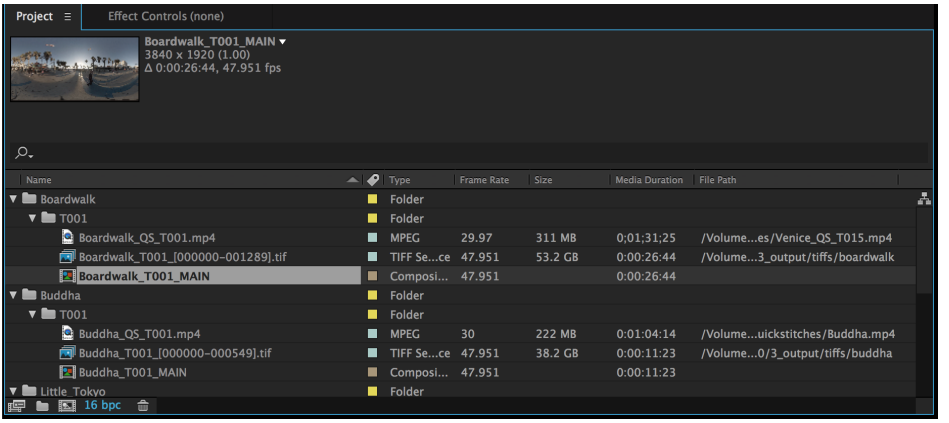
After you mask the tripod using the **Patching Nadir** method in Photoshop, import the PSD file into AE. This allows you to edit and update any work in Photoshop back into AE. This also applies to **Rotoscoping** with Mocha and editing audio using Audition. Keep all your work organized in the same take folder in AE.



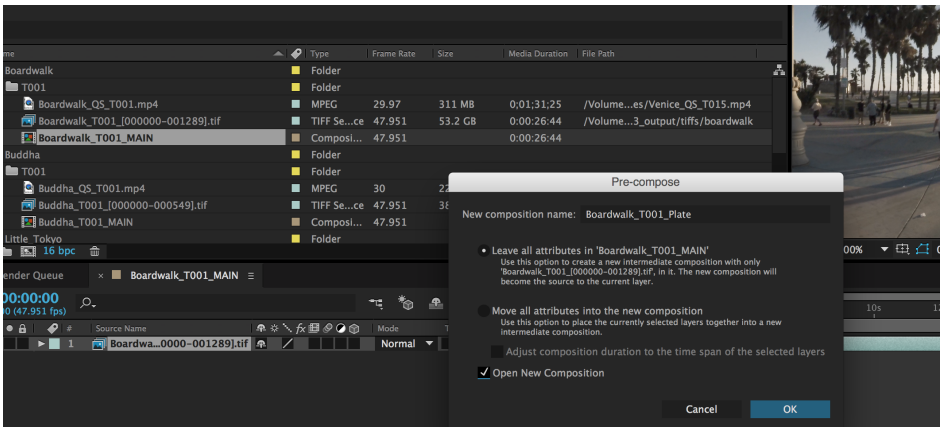
Pre-Comps and Shortcuts.

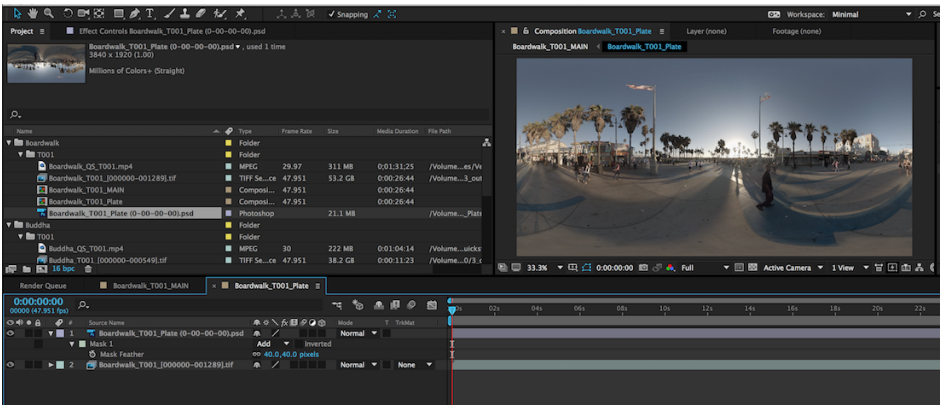
When preparing your master composition in AE for 360 editing, consider the potential adjustments that the client or creative director may ask you. To facilitate collaboration on the project, organize your project into steps, or “pre-compositions” for any future changes.

The stitched panoramas will render out of Autopano in equirectangular format. The center of the equirectangular stitch will be the starting orientation of the viewer in the headset. The director may want to change this position so the viewer enters the scene or experience facing a different angle. Instead of re-rendering your tiffs with a different panorama position, you can handle this right in AE. Precomp all your tiff sequences, matching their original dimensions and FPS. Rename the first precomp as Take or Scene name and add _Main as the step. This Main comp will become the finalized panorama that includes changes like **Patching Nadir** and fixing seams with **Masking Markers**.

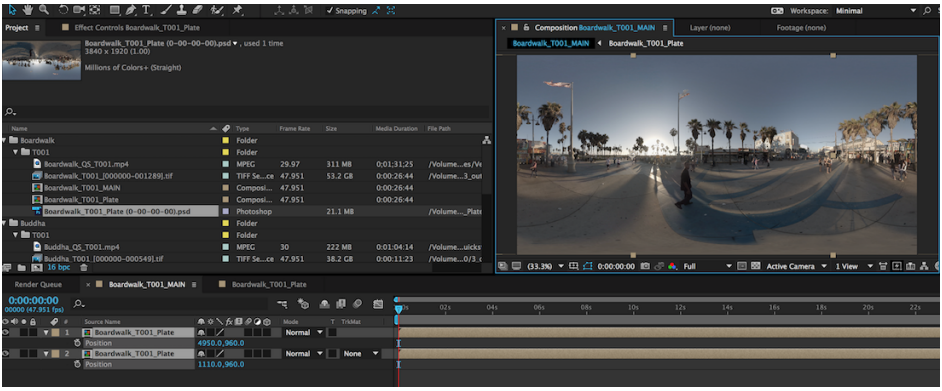


Let's precomp the layer and name it "Plate". In this precomp, add your Photoshop layer to patch the nadir and any work to fix seams.

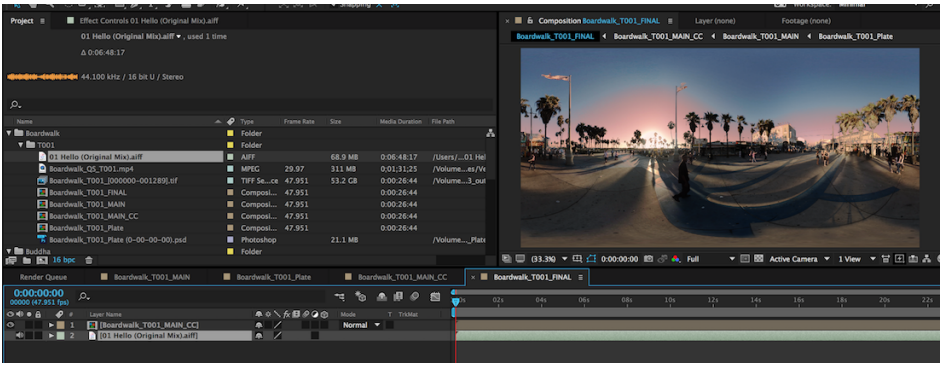




Select the "Plate" precomp from the _Main comp, using Command + D to duplicate the precomp, then P to change the X axis of the precomp on top. Add the width of your composition to the x value (ex: 1920 x value + 3840 comp width). Select both precomps together and move them horizontally to change the center of the viewpoint.



You may need to precomp in AE a lot more to fix some seams, recreate elements in the background, or add green screen footage. All this work should be done under the “Plate” pre-comp. Start a new composition or copy the _Main one and rename it the next step. For example, rename _Main_CC for Color Correction. Mute audio on all layers and handle the audio at end in the _Final composition, so there is only one video comp and one audio comp. After the first assembly is approved, import the EDL or Premiere sequence into AE to reassemble with the take comps.



Here are some short codes in AE:

- Command + D to Duplicate a layer.
- Command + Shift + D to Cut and start new layer at that frame.
- Command + Left/Right arrows to move timeline cursor frame by frame.
- Command + Click over timecode to switch with frames.
- Command + Option + F to Fit to Screen your layer with the comp width/height.
- Layer selected + B to start Work area at the frame your cursor is on.
- Layer selected + N to end Work area at the frame your cursor is on.
- Layer selected + I to go to the In point of your composition.
- Layer selected + O to go to the Out point of your composition.
- Layer selected + J to go to the In point of your Work Area.
- Layer selected + K to go to the Out point of your Work Area.
- Layer selected + R to quickly edit Rotation of layer.
- Layer selected + T to quickly edit Opacity of layer.
- Layer selected + P to quickly edit Position of layer.
- Layer selected + A to quickly edit Anchor of layer.
- Layer selected + S to quickly edit Scale of layer.
- Layer selected + L to quickly edit Audio Levels of layer.
- Layer selected + F to quickly edit Mask Feather of layer.
- Layer selected + , to Zoom in the preview area.
- Layer selected + . to Zoom Out the preview area.

Patching Nadir

Problem:

The tripod of the camera rig is visible and masking markers aren't removing it.

You have stitched your videos but the tripod still shows. You didn't **Shoot the Moon** to replace the camera rig and Autopano does not recreate missing pixels. When you try using the red masking markers to hide the rig, some weird blending or a black hole is generated in the panorama.

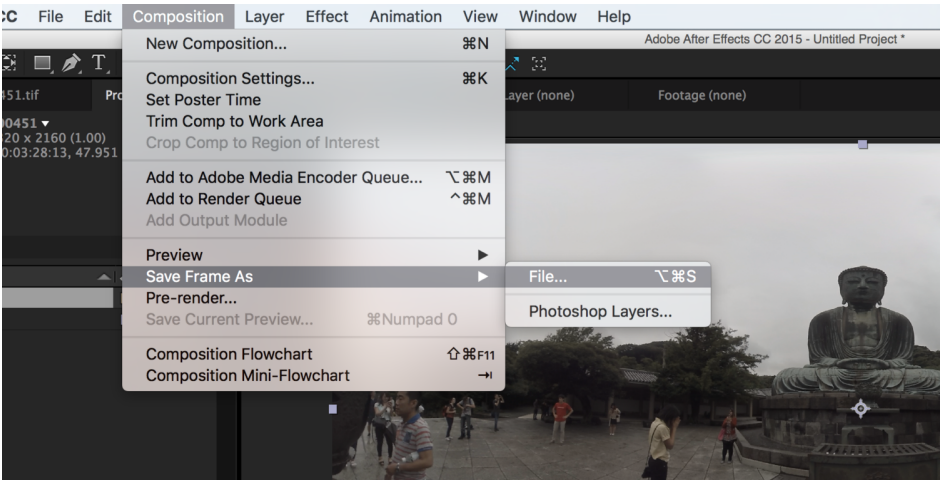
Solution:

Use Photoshop's clone stamp to recreate missing pixels.

Flip the panorama vertically to edit the desired area. Then convert your 2:1 Equirectangular panorama to 180° Fisheye / Domemaster format. After editing the nadir or zenith in Photoshop, convert back to 2:1 format and flip if needed to flatten the panorama.

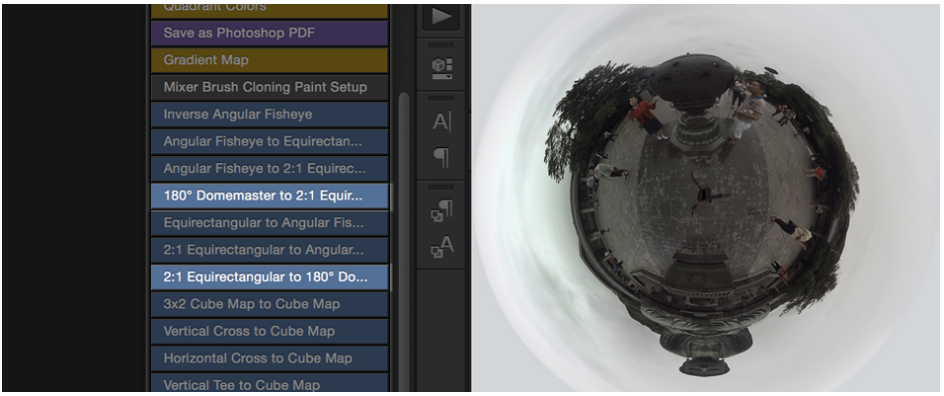
First, install Andrew Hazelden's Domemaster Actions for Photoshop.

After importing the image sequence into After Effects, create a new composition with it and save the first frame as a photoshop layer. Render the file, and open it in Photoshop.



First rotate your image 180 degrees if you are editing the nadir or zenith. Flatten the layer before applying any domemaster actions.

In the Actions list, select 2:1 equirectangular to angular fisheye or 180 domemaster. The panorama format is now converted to a planetarium view. Edit the tripod here using the stamp tool.

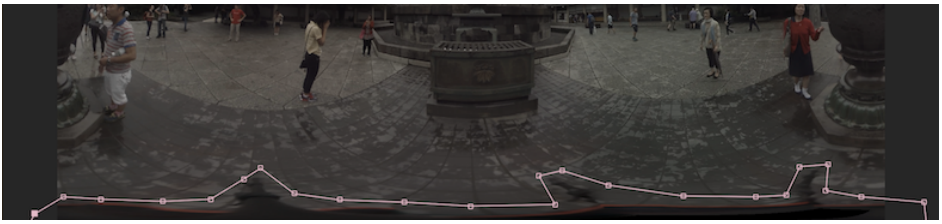


PROTIP: The stamp tool icon is located in the tool box. Press S on the keyboard to access it, then 'alt' to select area to clone. Click on the area with the tripod and apply the clone.

Afterwards, flatten your layers and apply the reverse domemaster actions, angular fisheye or 180 degree domemaster to 2:1 equirectangular. Then rotate the panorama 180 degrees if needed.

Back in AE, import the Photoshop layer and place the layer on top of your existing image sequence. The frame with the tripod removed will be used for the entire image sequence. Change the dimensions of the photoshop layer to 50% smaller if needed.

Using the pen tool, hide the layer and create a tight mask around the tripod from the original sequence. Show the hidden layer you created a mask with and adjust the feather to blend the edges of your mask with the original image.



Stitch Anything

Problem:

You need to stitch together footage with each angle shot at a different time.

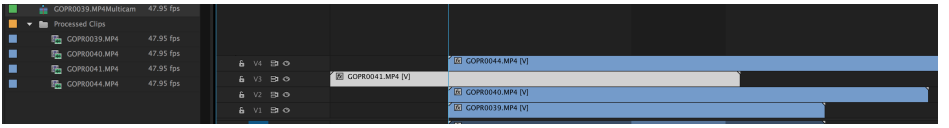
You shot different angles or different content with the same angle using one GoPro, DSLR or RED Dragon camera. You can't synchronize using audio or motion.

Solution:

Assembling ready-to-stitch camera footage.

Shooting with this method is usually for creative, quality, or financial reasons. Maybe you want to create an interesting or funny scene with the same subject in every angle performing different actions. You might want to composite super crisp high resolution cinema quality shots using one RED camera or you just want to experiment with new ways to stitch and composite.

More time will be spent on the edit, deciding what should be in each angle of the experience, visual as well as sonic. To synchronize the takes that were shot during different occasions, edit your first assembly with one video track per angle.



To stitch videos with completely different video settings, the overlapping area needs to feel seamless and natural for a 360 VR experience. Stitch

to defish your fisheye footage one angle at a time and blend the angles in AE. You can also create overlapping areas over your source footage in AE, render each camera and utilize Autopano's blending algorithm.

In this case, there are 4 angles with the same subject in each angle doing different things. Edit each angle in Premiere just as in the **First Assembly** chapter. Trim and place your clips in their respective video track timelines. Delete all empty or effect spaces between clips and render each video track for the entire assembly. When rendering your files, add the camera number for the corresponding angle. Each video should account for an angle in the field of view, with its background overlapping with the other cameras. The key is to stitch the background since the actions are happening fully within each camera.

Rotoscoping

Problem:

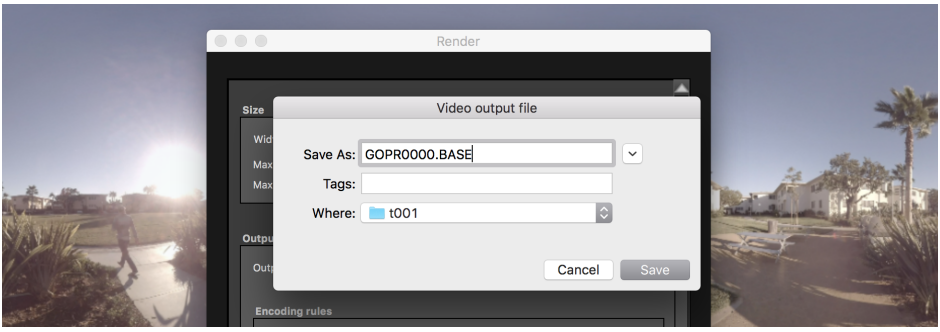
Your moving subject or object has complex seams and you've tried everything to fix it in Autopano.

Sometimes **Control Points** and **Masking Markers** aren't enough, and you need an alternative to deliver a perfectly stitched panorama. If you are not familiar with Mocha and rotoscoping, now is the time! Rotoscoping is a technique where a subject — either live or animated — is traced over, frame by frame, to create a matte so it may be composited over a different background or environment. Good news, all versions of AE come with a free version of Mocha, the tool for rotoscoping!

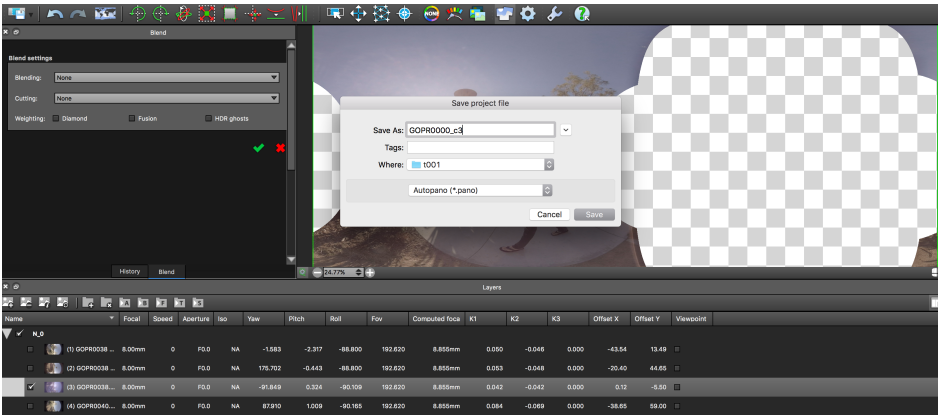
Solution:

Track First. Roto Second.

The process for rotoscoping over a stitched panorama starts with rendering a few different panoramas from Autopano. First, render your base panorama, the one with the best possible blending and least amount of seams in the background, as a 16 bit tiff sequence.

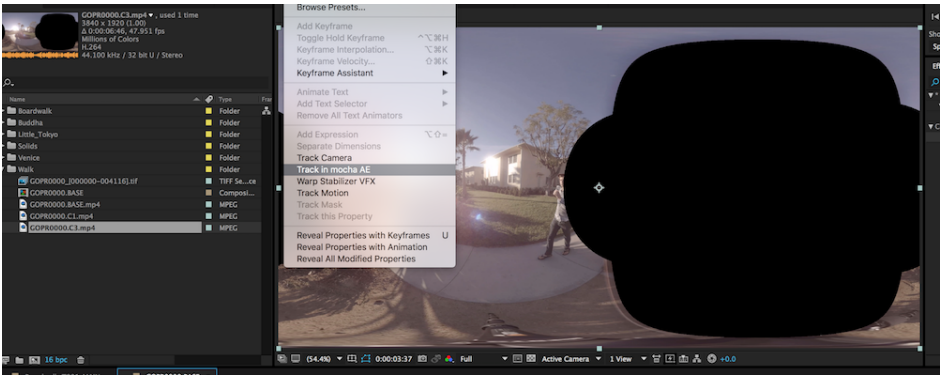


Then render only one camera using the same stitch template but without any blending. In APG, uncheck all layers/cameras, turn blending off, and check the one with the subject/object to roto. Render it at the same size as an mp4 and as a tiff sequence.

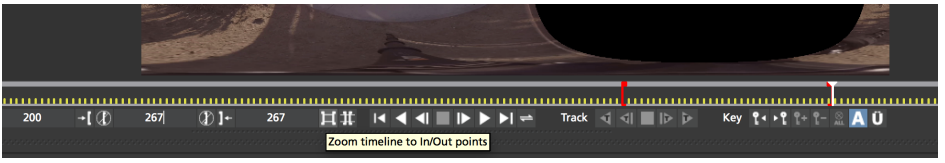


In AE, import both sequences under their take folder and create a new com-

position from the base tiff sequence, using the same FPS and dimensions. In the same composition, add the mp4 that contains only the object to roto on top of the base layer. Under Animation menu, choose Track in Mocha AE. Save your new project to the take folder location to easily access it later.

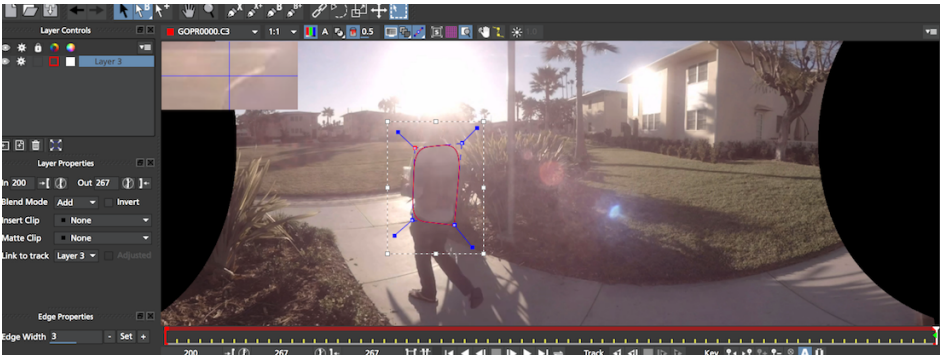


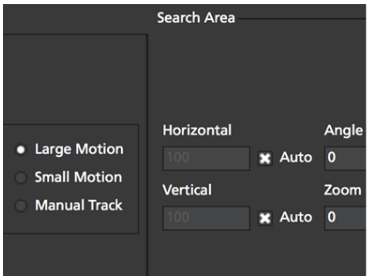
Before tracking our object, ensure you are working on the least amount of frames to speed up the work. Choose the start and end frame of the roto area that will be composited to mask the seam on your base panorama. In Mocha, go to the starting frame and click the “Set In Point” button located on the left of the timeline controls. Do the same for the Out point with your end frame. Select “Zoom timeline to In/Out points” under Movie menu or from the same controls.

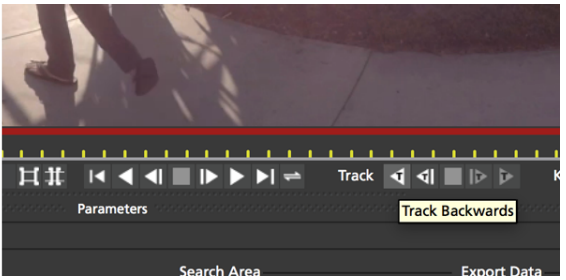


Now that you are ready to track motion with Mocha, press Command + L to use the X-Spline tool or Command + B for the Bezier tool. Go to the end frame of the work area and select a few points around the outline of the object you want to roto. There’s no need for a detailed shape yet. In the lower part of Mocha, locate the Motion parameters and select only the tracking data of Translation, Scale and Rotation. Press Shift + < key to track backwards. Adjust the X-Spline points from the starting frame, then

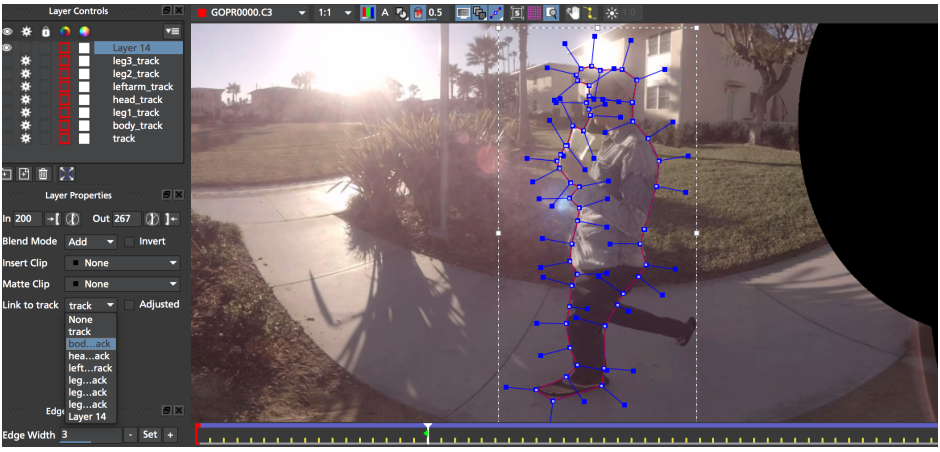
Shift + > to track forward.



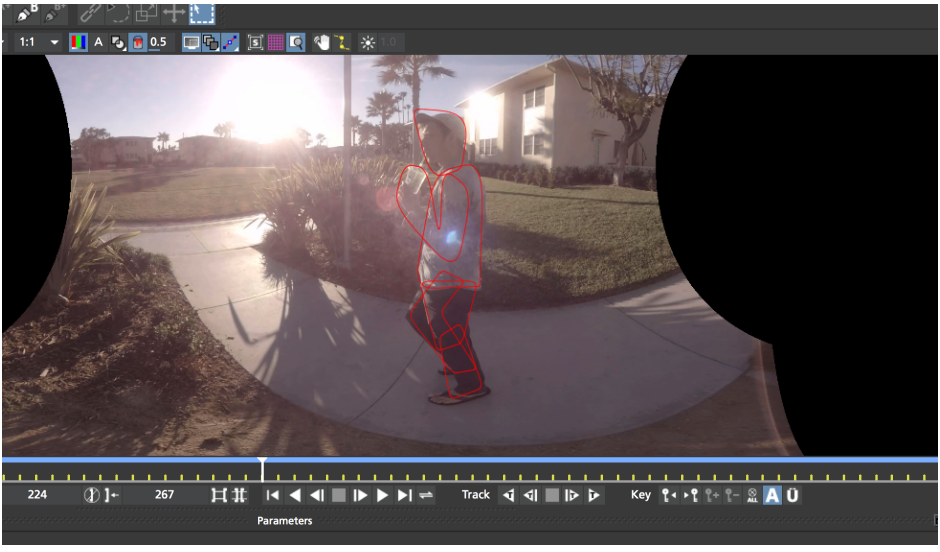




After the tracking is done, rename this roto layer under the Layer controls (left area) to “track” and hide it by unchecking the eye icon. Press Command + L or B to start a new roto which will be the detailed roto mask. Take your time with selecting some of the points and try rounding the shape with the blue splines. When satisfied with the mask, uncheck the “process” icon next to the eye icon of the Layer controls for the layer you just created. Then find the “Link to Track” dropdown under Layer Properties and select the previous layer renamed “track”. You just linked your detailed shape to the tracked motion of your previous layer. Use the playback controls to check and verify the motion.

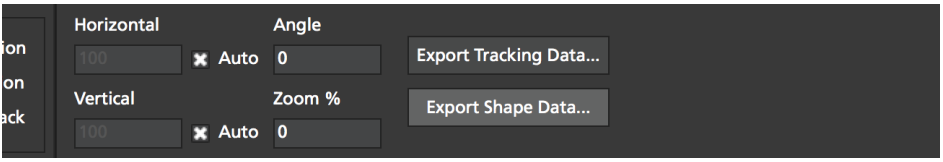


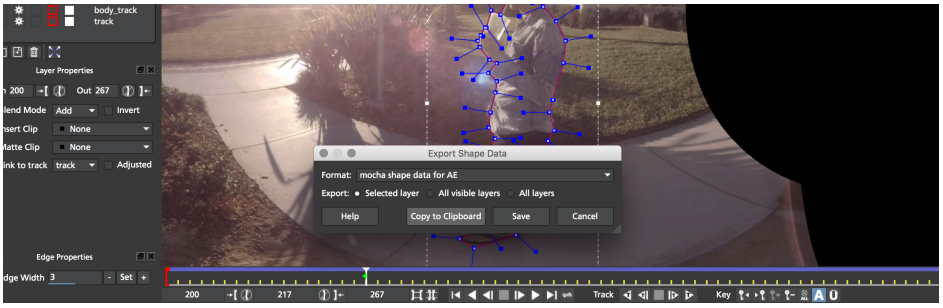
This is the bare minimum to understand how tracking and rotoscoping with Mocha works. When rotoscoping a moving subject with multiple movements happening simultaneously such as head rotation, arms bouncing around, or legs walking, consider all movements separately. Following the same steps, create a quick mask with X-splines, track backward, adjust your points, track forward, and then create your detailed mask to later link to the tracked layer. The more points, the more time Mocha will take to track.



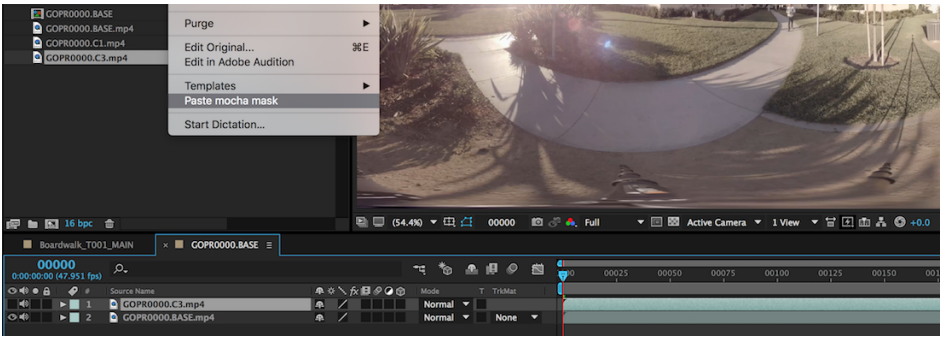
Paste Mocha Shape.

After tracking your object in motion and creating a detailed mask linked to the tracked motion, you can easily transfer the data over from the free version of Mocha to AE. Select the detailed layer(s) from the Layer controls and in the lower part of Mocha, choose “Export Shape Data..”. In the popup, make sure the selected layer is the one you want to paste, then Copy to Clipboard.

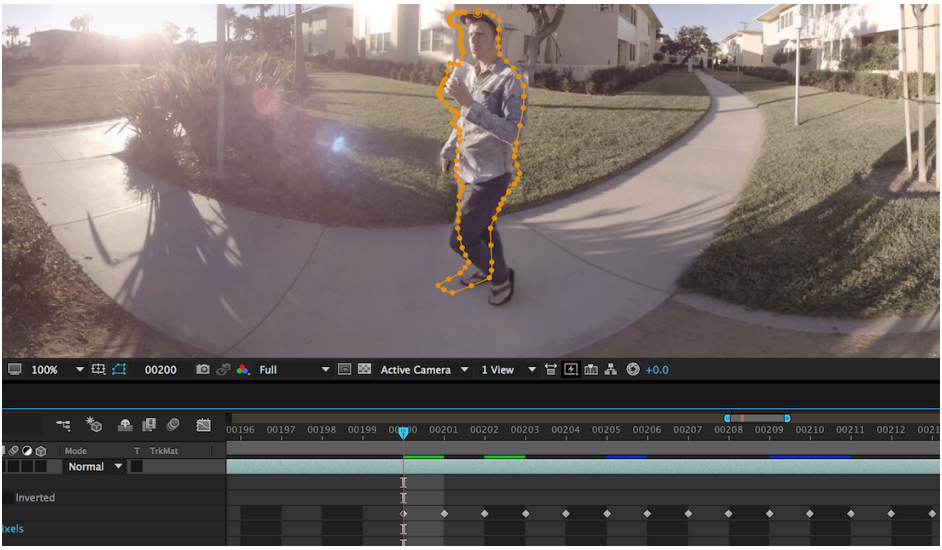




Back in AE, select your footage layer and place the cursor to the starting frame, or press I to go to Frame 0. Then under the Edit menu, select Paste Mocha Shape. AE will create a custom Mask based on the tracked mocha shape.



Go to the frame that has the first keyframe of the tracked roto and press M to show the Mask options. Each spline can also be readjusted frame by frame in AE. After rotoscoping and exporting the object onto your base panorama, follow the instructions in **AE Comping** to blend this roto.



AE Comping

Problem:

You need to comp two stitched videos warped differently in After Effects.

Compositing in After Effects is its own art form, as many tools can be used to achieve similar results. The goal is to perfectly blend one footage over another. AE is an alternative solution if stitching in Autopano is not enough to correct a few seams or if some external footage needs to be integrated into your panorama.

Solution:

Using Masks.

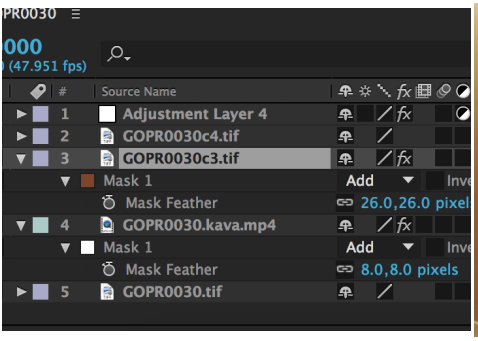
Using the pen tool to create a mask over a static shot is the fastest way to composite an object into your panorama. For moving shots, first motion track using a null object and link your mask to it for **Rotoscoping** with Mocha. Any green screen footage will benefit from **Chroma Keying** techniques much faster than rotoscoping, but results tend to be a bit rushed compared to rotoscoping.

Try to create a large mask with points following along the architecture of the distant background that contains the object or subject to hide unfixed seams in AVP. Sometimes, it is just enough. For moving shots, motion track

using the AE tracking points or Mocha. Depending on your panorama, a large mask may create more difficulties to blend than a tight mask around the outlines of your object or subject.

When satisfied with your mask and its movement over time (see **Rotoscoping** for fast tracking), compare RGB histograms between the footage being comped and the base footage. Levels is the best plugin to correct exposure in After Effects and has the RGB histogram that is needed. Sometimes it is enough to bring the mid light up or down to lighten or darken the shot that needs to be comped. Keep the edge of your mask sharp to better gauge how much gamma adjustment is needed for a nice blending of the colors.

Press M on the selected layer to bring up the Mask parameters. Start by expanding the mask by 2 to 5 pixels, and then increase the feather of its edges. You can see in realtime what values are best for blending the comp into the base panorama.



Blending with different lens distortion.

Compositing footage in a 360 panorama gets really tricky quickly due to lens distortion and warping. To fix parallax seams, render your stitched panorama as a tiff sequence. Render all the rest of your cameras as well with the same render settings, except without blending, just the same warping and positioning.

Using the mesh warp tool for static shots

Bring the mesh warp onto your mask and add additional rows and columns to adjust the warping. The mesh is based on the entire footage and not the mask shape you created. The mesh nearby the mask shape can be edited better with more columns and rows. Start adjusting the verticals without touching your horizon. Re-adjust your mask shape and feather until both the background and your mask blend nicely together.

Using the optics compensation for moving shots

When working with moving shots, if your mask is linked to a motion-tracked null object or your shape and data copied from **Rotoscoping**, adjust your optics compensation slightly. If shooting with fisheye lens, reverse the compensation to defish the distortion.

Stitch to Defish

Problem:

You want the fastest option to preview fisheye footage in a VR headset.

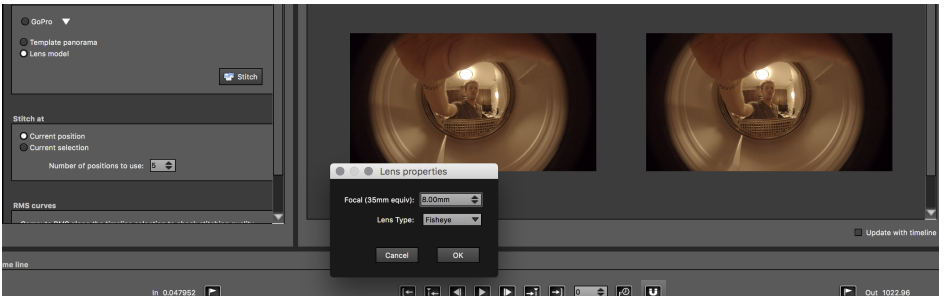
Just like the **Dailies Quickstitch**, you need to preview every piece of fisheye footage you recorded. Even with the Optics Compensation in AE, the scaling may be off or the distortion is not handled correctly.

Solution:

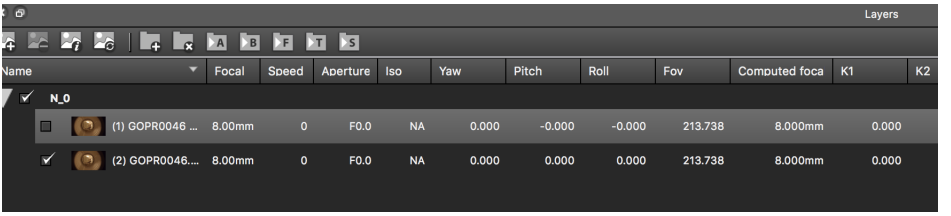
Way to go, Autopano!

Autopano will not only recalculate and adjust your lens distortion, but will also map it with the right scaling into a 360 x 180 LatLong projection that can be rendered for an instant preview in a VR headset.

There's a catch though. Autopano can't import only one video because it is a stitching software, and needs at least two videos to stitch together. Export a black video from After Effects with the same configuration as your video (same FPS, size, and length) to defish. Another method is to duplicate your video and import both together.



Autopano will map any video you import onto spherical geometry. Import your black and original videos and select the focal length and distortion before stitching. Stitch and click Edit to open APG. Inside APG, uncheck the layer with the black video or duplicate of your video. AVP will usually blend your video with the black video, causing the overall lighting to get darker. Under the Preview tab, set all blending and weighting to None, then Update. Lastly, launch the Image properties window from the Layers panel if your video looks too scaled down. Use the circular crop tab to adjust the area. This should help scale up your video to the 360 space.



Good news! If you are unfamiliar with 3D software like Maya or Blender, you can create a 3D title in AE and render it out as a lossless mov with a duplicate or black video. Try doing the same with your title in Autopano to get the best warping for viewing your title in a VR Headset. Render a tiff sequence of this title from AVP to your AE assembly without warping.

Chroma Keying

Problem:

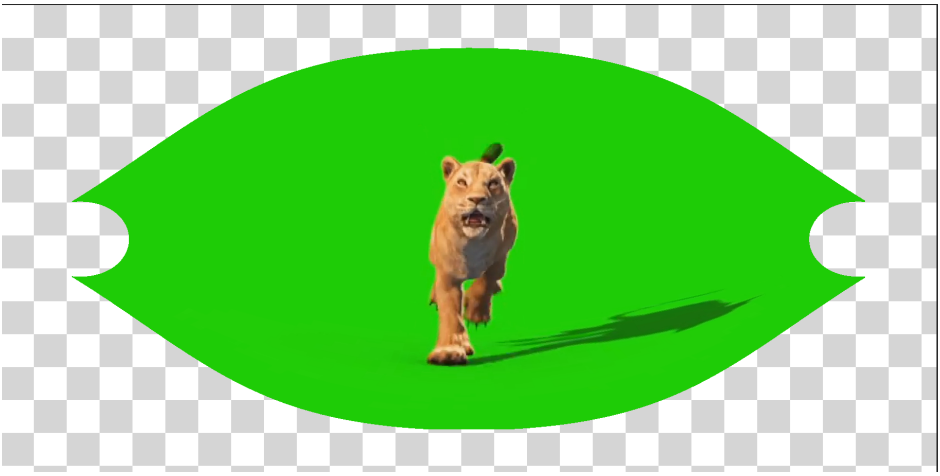
You need to comp a green screen plate into a stitched equirectangular video.

Creating VFX that is warped correctly in 360 space can be time intensive work. You may get away without changing your projection or using different warping plugins, but the result is not the best.

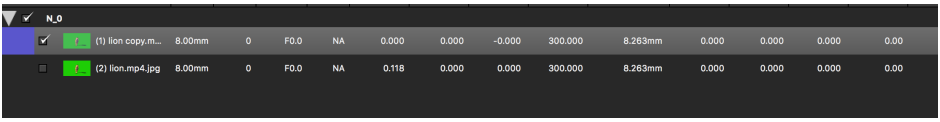
Solution:

From Autopano to Keylight.

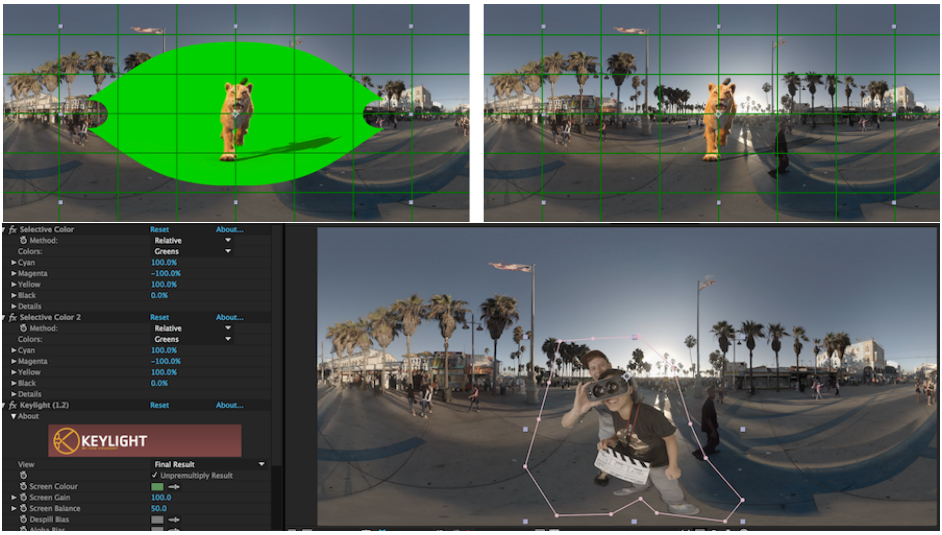
Basic green screen footage needs to be comped in your 360 panorama. The footage can be filmed with any camera like the RED, Arri, DSLR, or with the same 360 rig. Shooting with the same 360 rig makes the job a lot easier. With any green screen footage, use AVP to unwarp and reproject onto a sphere.



Import your footage and click Edit to open APG. Uncheck the unnecessary video layers to render only the green screen with the right warping for a LatLong 360x180. If shot with a fisheye lens, use the **Circular Crop Factor** to scale your video up. You can also set the yaw and pitch of your green screen layer to 0 to center it and change the FOV value, which should help scale your footage in the 360x180 projection. Render this as a 16 bit uncompressed tiff sequence.



Import into AE and add the Keylight 1.2 plugin onto the green screen tiff sequence. If your green screen was perfectly handled during production, use the “Screen colour” color selector to key out the green in your video. Otherwise, play around with the Screen Matte parameters to adjust the green keying. You can also increase the greens of your screen by using the selective color effect.

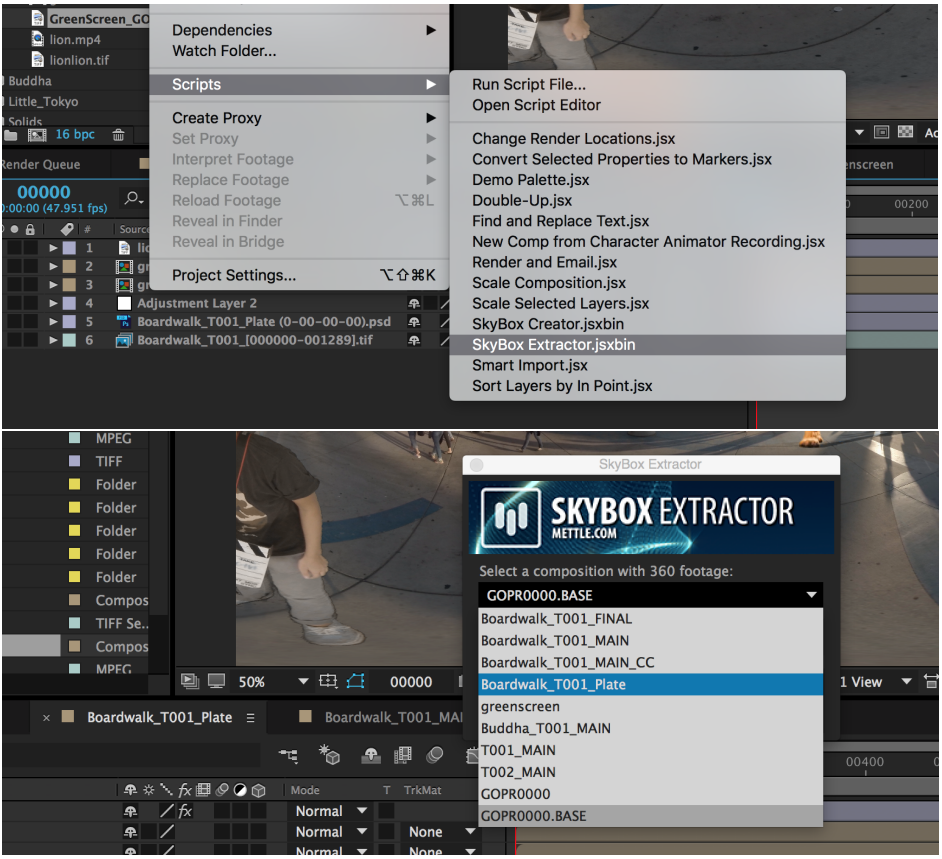


If your keyed object was not properly warped, it's safe to place it on the center horizon of your panorama. Scale it down to fit between the first row up and down on the proportional grid to minimize the potential for distortion.

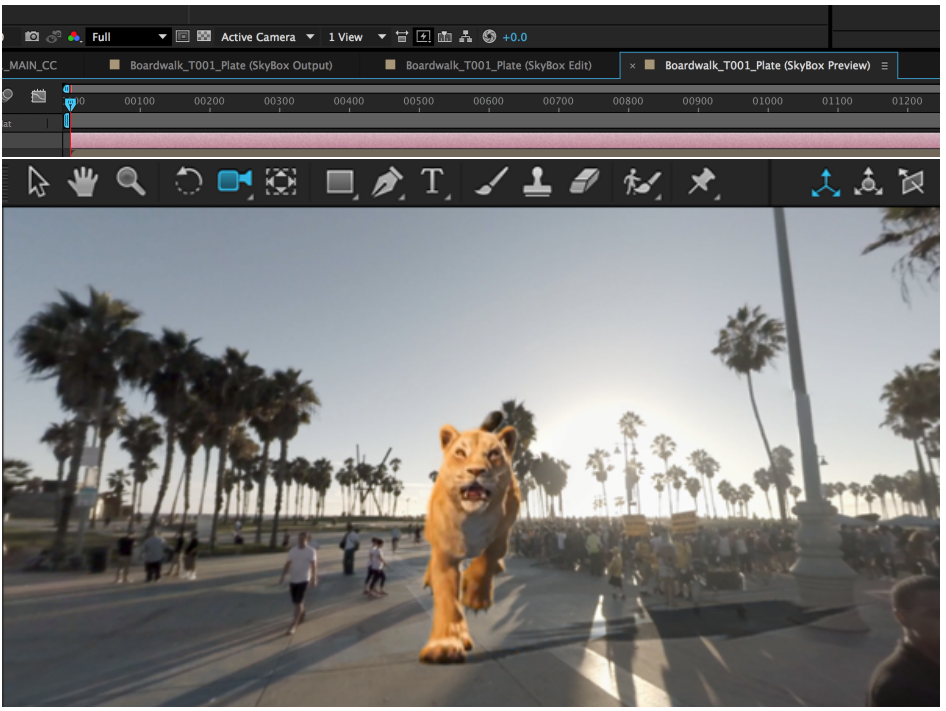
SkyBox is your friend!

You want to animate your object and have it come from the top of your panorama to the center point, where your viewer is facing. LatLong projections can get tricky, as you may not be able to control the distortion required for the object to remain undistorted when the viewer looks up in the sphere.

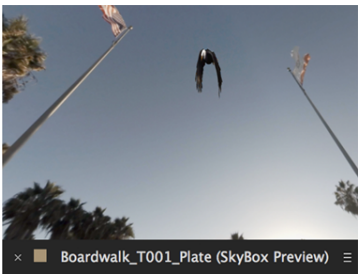
In AE, open your plate composition and download the plugin SkyBox from Mettle. Under scripts in File, select SkyBox Extractor. Then choose the plate comp to extract and run the script.



3 compositions will automatically be created. One comp is your Output, one your Edit comp and one for Previewing using the Camera cursor.

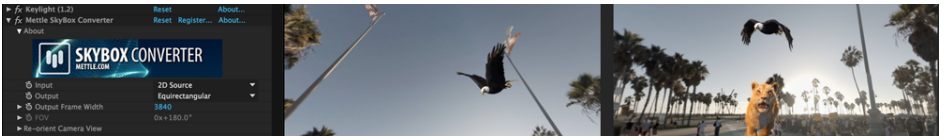


To animate any 2D, 3D or green screen elements, head over to your plate composition where you can add your layers to animate. For example, this eagle has been keyed out and placed on top of the base panorama. The warping is incorrect when previewing it via the Preview comp.



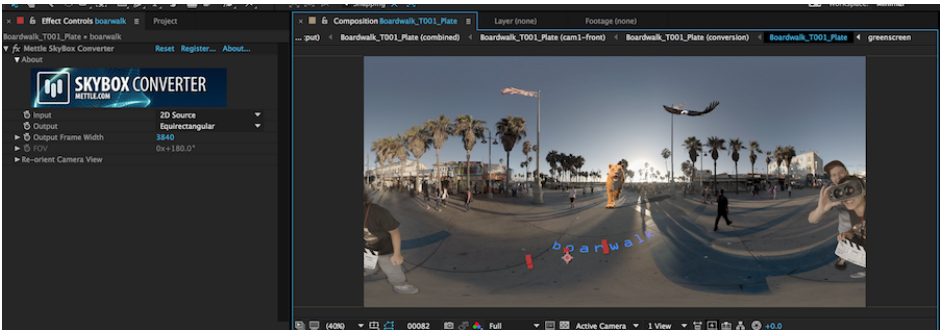
You need to convert the warping by applying the Mettle SkyBox converter, located in your AE effects. Drag the effect on top of any layer and SkyBox

will convert and unwarp the right way for you to start animating.



All elements have been converted and you can start keyframing and animating just like you would with any other AE project. Use the Preview comp to check the warping and adjust your animations as necessary.

You can also use SkyBox to convert text elements and create title animations for a LatLong 360x180 projected output.



Color Grading

"Colour is the keyboard, the eyes are the hammers, the soul is the piano with many strings. The artist is the hand which plays, touching one key or another, to cause vibrations in the soul."

- Wassily Kandinsky, Concerning the Spiritual in Art

Problem:

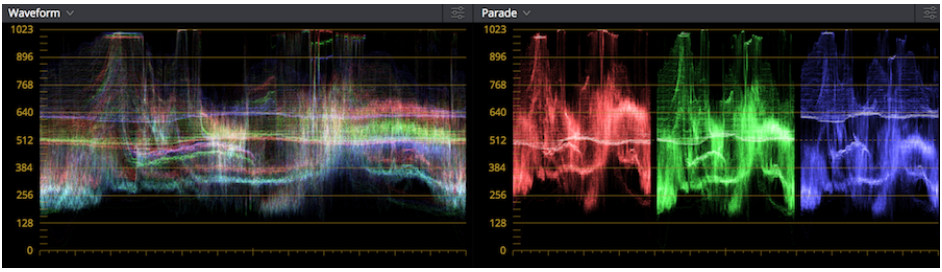
After coloring the blacks, you get more banding. After sharpening, a cable appears at 180 degrees.

Color grading a 360x180 LatLong is not like coloring any other flat video. Coloring the lows, mids and highs can introduce unwanted banding. How do you color grade, sharpen and blur as you normally would?

Solution:

The ultimate sophistication. DaVinci Resolve.

Resolve is a color grading platform first and foremost. Designed to allow the colorist the ability to quickly correct hundreds of shots while keeping track of all the grades, Resolve is a great solution to color grade after fine stitching your footage but also for **Color Matching** your individual cameras before stitching. The RGB histogram is much larger than in AE or Premiere, easing the process for color matching cameras.



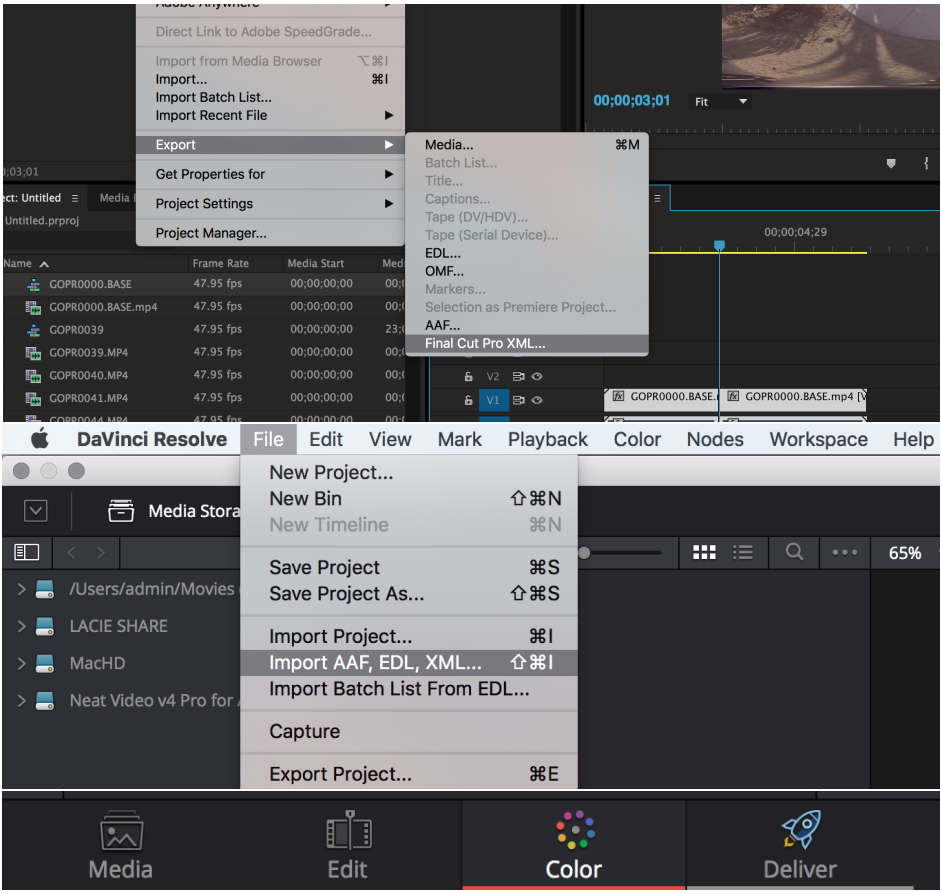
You've stitched and edited all your shots nicely with AVP, AE and Premiere. Now it is time to color grade using the industry standard, Resolve! When working with many softwares, bringing footage in to one and then another, also known as the "roundtripping" method, you need to be well organized. Keep your source footage in the source folder and separate all your work from different softwares into folders named specifically by software. For example, you would set an Autopano folder where all of your stitching work happens, a Premiere folder for your edits and XML files, a Resolve folder for color grading, and maybe even a Maya folder if you plan to add 3D assets to your project. Most of the work will be data that shouldn't be moved around and rendering should always target a folder named "Output".

▼ 1_source	Oct 31, 2015, 2:02 PM	--	Fol
▶ audio	Oct 31, 2015, 2:02 PM	--	Fol
▼ video	Oct 31, 2015, 2:02 PM	--	Fol
▶ floor	Oct 30, 2015, 6:32 PM	--	Fol
▶ take1	Nov 4, 2015, 11:18 AM	--	Fol
▶ take2	Nov 4, 2015, 12:06 PM	--	Fol
▶ take3	Nov 18, 2015, 2:15 PM	--	Fol
▶ take4_plate	Nov 4, 2015, 11:15 AM	--	Fol
▼ 2_work	Today, 4:50 PM	--	Fol
▶ ableton	Nov 4, 2015, 12:19 AM	--	Fol
▶ ae	Nov 4, 2015, 12:23 AM	--	Fol
▶ autopano	Oct 31, 2015, 2:03 PM	--	Fol
▶ davinci	Today, 4:50 PM	--	Fol
▶ premiere	Today, 4:50 PM	--	Fol
▼ 3_output	Nov 4, 2015, 9:33 AM	--	Fol
▶ audio	Oct 31, 2015, 1:47 PM	--	Fol

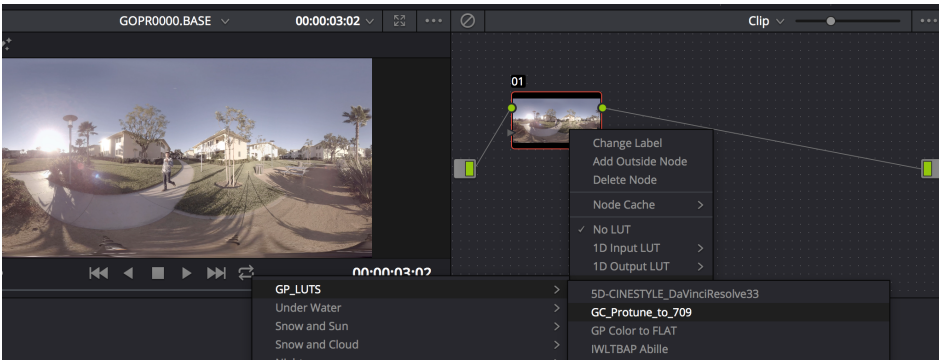
To quickly color grade your GoPros before and/or after stitching, you will want to use a LUT or Look Up Table. A LUT is a color transform, a set of numbers that change the colors of an image. They are used to correct log

exposure and for applying looks, such as emulating a 35mm analog film look. LUTs can be applied in many applications including DaVinci Resolve, AE, Premiere, Final Cut Pro, etc.. LUTs will save you time for converting your camera footage to the right color space. Make sure to use LUTs based on the camera used in production. You can easily find GoPro and other camera LUTs via a Google search.

From your Premiere project, export your edits as "Final Cut Pro XML" and in DaVinci Resolve, import the same XML. Now you are ready to color grade your shots. Go to the Color section of Resolve.

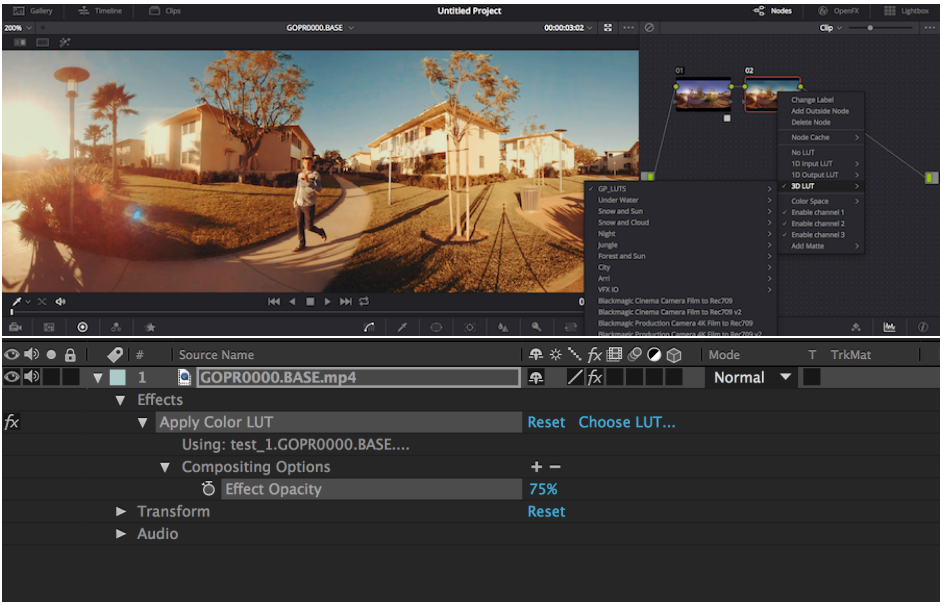


Since you shot with Protune on, your individual cameras or stitched panoramas will be flat. First, to convert the log footage to Rec.709 space, select Nodes and right click on your clip to add a 3D LUT.



When coloring 360 videos, some LUTs may correct curves too much. This means more banding can be introduced. While it is a normal problem in grading flat videos, in 360 videos, banding is an even bigger problem. A/B test your grades before deciding on the final color grade. In a VR headset, banding and colored shadows or blacks are very noticeable and distract from the reality of the experience. An important **Mise en Place** is necessary to avoid banding. Working in a 16 bit color mode is considered sufficient to render frames in Rec.709 or sRGB.

Apply the first 3D LUT to convert from log to Rec.709 and then add a new node (alt + S) to color grade further or apply a 2nd LUT to emulate a film look. When the offset is adjusted too much and blacks are colored on the 2nd pass, you can test different transparencies of the LUT look by adjusting the intensity under the Lumetri Color plugin in Premiere or the opacity of your LUT adjustment layer in AE.



PROTIP: Some great LUTs to correct log exposure or emulate film looks can be downloaded from GroundControl, Neumann Films or OSIRIS. To import them into Resolve, under your Project Settings open LUT folder in Color Management tab and then copy all your downloaded LUTs here and press Update Lists.

Converting your individual cameras to Rec.709 will also help AVP auto-detect control points and perform a better overall stitch. You can then apply your 2nd color grade after the stitched panorama is rendered.

What's that cable?

When you sharpen or blur your 360 panoramic videos, a transparent or black cable will appear behind you when viewing in a VR headset. The cable is caused by sharpening or blurring your images and the effects utilize the edges of your equirectangular video to distort colors or pixels. Even if you are sharpening in SkyBox and able to preview all around the 360 space, rendering your video with a layer sharpening or blurring your base panorama will generate a line caused by the remapping of the video onto a sphere.

Since the left and right edge of your video have to match perfectly in order to create a seamless 360 video, you will need to only sharpen certain areas of the equirectanglar video.

To avoid the visible transparent cable from appearing at 180 degrees from the center of the video, use masks and feather the edges of the masked areas. In DaVinci, use the rectangle window and soften the edges of the rectangle area and then sharpen inside the area.

Noisy Footage

Problem:

You shot a night scene and your GoPros are too noisy.

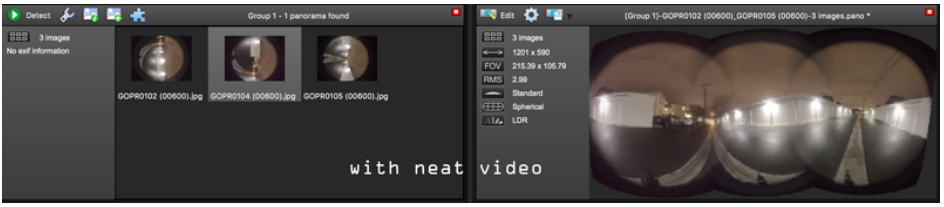
Shooting with GoPros even when using Protune can not compare to the quality of a DSLR. Adjusting the ISO, Low Light and EV Comp options will not guarantee you better nightime shots. It will be took dark and introduce noise. It could be unstitchable and distracting in a headset. For optimal conditions for shooting with GoPros, check the **Lighting** chapter.

Solutions:

Denoise with Neat Video.

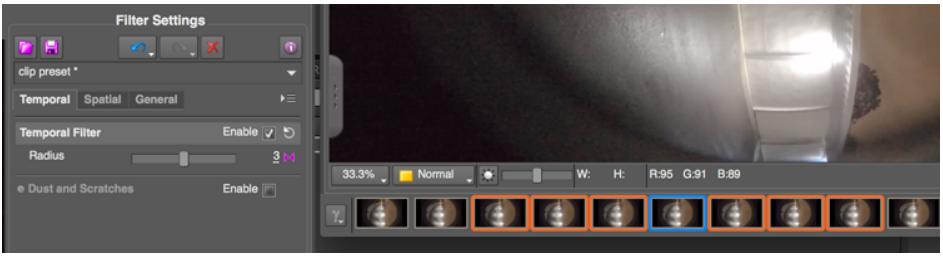
Install the Neat Video plugin for AE or Premiere on PC or Mac. The home version will only denoise footage up to a resolution of 1920x1080 so you will need to install the Pro version.

Neat Video does a great job at denoising videos and applying it on your individual cameras before stitching will help find more control points and in some cases will permit you to even stitch at all. Below is an example of stitching 3 images by auto-detecting the points and geometries right from APG. With Neat Video, some noisy footage can actually be a problem for APG.



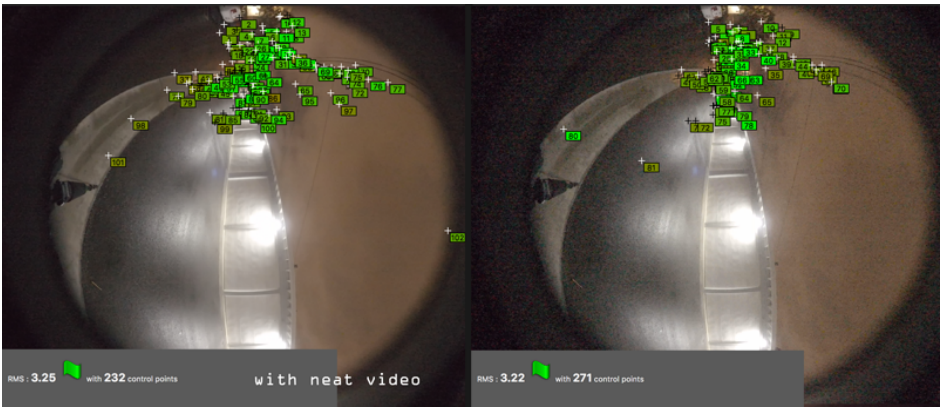
Import your individual cameras into AE and create multiple new compositions from files. Find the "Reduce Noise" plugin in AE effects and apply it to each of your clip layers. Make sure the AE preview is set to Full resolution and disable the Fast Preview for optimal performance. Click on "prepare" from the effect controls of Reduce Noise effect. Register your license of Neat if you haven't already. You will auto-create a noise profile by selecting Auto Profile and then refine the area by moving the blue box over an area which contains most of the noise and without difference in colors. For example, place or draw a green box on the noisy sky or ground of your video.

The noise profile captured from the selected area will be applied to the whole frame and throughout the duration of your individual clips. Use the temporal filter to increase the number of frames before and after the selected frame. Neat will calculate the amount of reduction better for upcoming frames. Use the spatial filter rarely.



Render your videos separately as .mov files or as a tiff sequence that you can later convert to mp4.

After comparing noisy footage before and after using Neat Video in AVP, here are the results. AVP found more control points with default auto-detection and the noise has been greatly reduced.



Hello FFmpeg

Problem:

You need a tool for compression.

Whether you are just starting the ingest process and need to concatenate multiple sequences, want to combine left and right eye into a well scaled over under, or want to render multiple compression tests, FFmpeg is the perfect tool for all. At any step of the 360 workflow, understanding FFmpeg will come in handy.

Solutions:

Hello, FFmpeg!

FFmpeg is the leading multimedia framework, able to decode, encode, transcode, mux, demux, stream, filter and play pretty much anything that humans and machines have created. It supports the most obscure ancient formats up to the cutting edge. No matter if they were designed by some standards committee, the community or a corporation. - FFMPEG

Install the right binary (Mac)

FFmpeg has always been a very experimental and developer-driven project. New features are added constantly and the default PC and Mac binaries may not have the needed filters or H.265 codec enabled.

For Mac users, the right binary to install is the version 2.7.2 built by Helmut Tessarek. It is compressed with 7-zip, so you may need to get a decompressor first. Use Keka (not open source, but free).

Once you unzip the binary with Keka, open your Terminal applications by

using the search spotlight. In the terminal, you will first need to show all the hidden files and folders on your Mac. Enter this line and press return:

```
defaults  write  com.apple.finder AppleShowAllFiles YES
```

Use the force quit menu under the Apple icon to relaunch the Finder. The hidden files should now appear in your finder window.

Next place the unzipped FFmpeg binary, which should be a 30 MB file, into the shared user folder containing all your other binaries. Using the finder, Go to the Computer folder (Macintosh HD unless it was renamed) or Command + Shift + C. The folder to place the FFmpeg binary should be located at usr/local/bin, and if the folder doesn't exist, create it. Authenticate by inputting your password.

Now, back in your terminal window, use the arrow up key to bring back the line to show all hidden folders and then replace YES with NO to hide them again. Relaunch the finder. In the terminal window, type 'ffmpeg' and you should now see the right version of the binary installed.

Install the right binary (Windows)

On Windows the current version of FFmpeg is 2.8.2. It supports both the H.264 and H.265 video codecs, and the drawtext command which is used for creating timecode overlays.

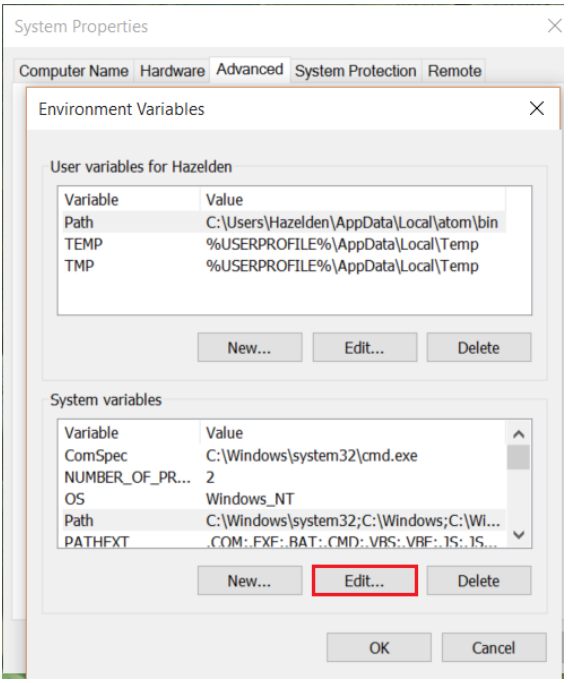
When you download FFmpeg, you should install it in the "Program Files" folder.

Then to make it easier to run ffmpeg.exe from the command prompt you need to add the FFmpeg "bin" folder to your system's environment PATH variable.

This is done by opening the System Control Panel using the Windows + Pause/Break keys. Then in the System Control Panel, select the Advanced System Settings option. A System Properties dialog will appear. Select the

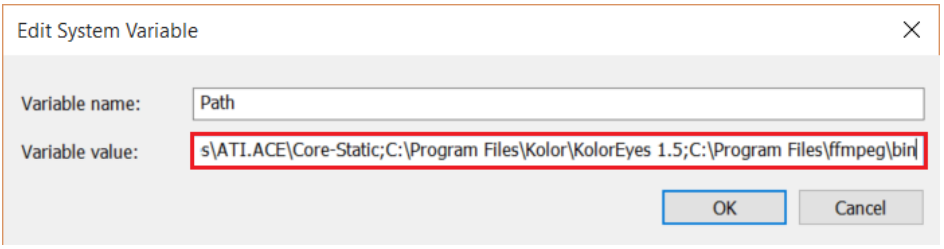
Environment Variables button.

Now in the lower part of the Environment Variables dialog, there is a System Variables section. Select the "Path" entry and click the Edit... button. This will open up the Edit System Variable dialog.



Add the following text to the end of the Path variable and then click the OK button to accept the changes:

;C:\Program Files\ffmpeg\bin



Since the FFmpeg bin folder has been added to the system's Environment PATH variable, you will now be able to run FFmpeg just by typing in "ffmpeg" or "ffmpeg.exe" in a new Command Prompt window.

Convert Files

FFmpeg is the best tool to quickly convert video and audio files to almost any format. For example, type this line in the terminal to convert a .mov file into an .mp4 file:

```
ffmpeg −i video.mov video.mp4
```

Now let's convert a tiff sequence into an .mp4 file. First replace the logical order of your tiff numbers with %05d instead of five zeros 00000. Then an image sequence will require a frame rate to be converted into a movie file using the -r option. Try this on a tiff sequence:

```
ffmpeg −i sequencename_%05d.tiff −r 25 sequence.mp4
```

Concatenate Sequences

When recording video with the GoPro HERO4 Black, notice the files are cut off anytime after 3.8 GB. Depending on the video mode, this could be 8-11 minutes. The take will be split into chunks. This is because the microSD cards are formatted FAT32 which limits up to 4 GB. If you are using a 64 GB card, it will be formatted exFAT which normally allows larger file sizes. However, the GoPros will still limit the file size to 4 GB. You can shoot a take as long as you want until the cards fill up or the battery dies. The individual segments will need to be concatenated into one file before stitching.

Use FFmpeg to concatenate your sequences. It will be much faster than using a video software's rendering engine, like importing into AE and exporting.

Create a file mylist.txt with all the files you want to have concatenated in

the following form (lines starting with a are ignored):

```
file  '/path/to/video1.mp4' file  '/path/to/video2.mp4' file  '/path/to/video3.mp4'
```

Note that these can be either relative or absolute paths. Then you can stream copy or re-encode your files:

```
ffmpeg -f concat -i mylist.txt -c copy output.mp4
```

Combine Videos into Over/Under or Side/Side

If you need to combine your videos into an Over/Under, left eye on top of the right eye, here's the one line to enter in your Terminal after changing the filenames to match yours:

```
ffmpeg -i left.mp4 -vf "[in]  pad=iw:2*ih [left];  movie=right.mp4 [right];[ left ][ right ]
overlay=0:main_h/2 [out]"  output.mp4
```

And for Side by Side:

```
ffmpeg -i left.mp4 -vf "[in]  pad=2*iw:ih [left];  movie=right.mp4 [right];[ left ][ right ]
overlay=main_w/2:0 [out]" output.mp4
```

Map Multiple Audio Tracks to a Video

If your tiff sequence or video has no audio, you could use the default stream selection parameter -i, to add one audio track to your video:

```
ffmpeg -i sequence_%05d.tiff -i audio.mp3 -codec copy -shortest output.mp4
```

When you need to add multiple audio tracks to a video, for example, for later use with head tracking, then you will need to understand the -map option.

```
ffmpeg -i video.mp4 -i audio1.mp3 -i audio2.mp3 -map 0:v -map 1:a -map 2:a -codec
 copy output.mp4
```

0:v – The 0 refers to the first input which is video.mp4. The v means "select video stream type".

0:a:0 – The 0 refers to the first input which is video.mp4. The a means "select audio stream type". The last 0 refers to the first audio stream from this input. If only 0:a is used, then all video streams would be mapped.

1:a – The 1 refers to the second input which is audio.mp3. The a means "select audio stream type".

-codec copy will stream copy (re-mux) instead of encode. If you need a specific audio codec, you should specify -c:v copy (to keep the video) and then, for example, -c:a libmp3lame to re-encode the audio stream to MP3.

-shortest will end the output when the shortest input ends.

H.264 vs H.265

Apple's current preferred compression format, H.264, has been a huge success as being the most flexible codec widely used for streaming videos, capable of handling stereo 3D videos, 48-60 FPS and even 4K resolution. The problem with H.264 however, is that while it can handle these types of encodes, it can't do so while simultaneously keeping file sizes low. A new standard is necessary to push file/stream sizes back down while driving next-generation adoption, and that's where H.265 comes in. It's designed to utilize substantially less bandwidth thanks to advanced encoding techniques and a more sophisticated encode/decode model.

In order to obtain a copy of FFmpeg with libx265 support, you need to build it yourself, adding the –enable-libx265 configuration flag, with x265 being installed on your system. Here's how you would convert and compress a tiff sequence using the H.265 enabled binary:

H.264:

```
ffmpeg −r 29.97 −i sequence_%05d.tiff −i audio.mp3 −c:v libx264 −preset fast −maxrate
 20000k −bufsize 20000k −vf scale=3840:1920 −pix_fmt yuv420p −crf 18 output.mp4
```

For H.265, options are passed to x265 with the -x265-params argument such as:

```
ffmpeg −r 29.97 −i sequence_%05d.tiff −i audio.mp3 −c:v libx265 −preset fast −maxrate
 20000k −bufsize 20000k −vf scale=3840:1920 −pix_fmt yuv420p −x265−params crf=18
 output.mp4
```

Almost Done!

Problem:

You are testing playback of the final delivery and it is not playing or too large for the device.

There are many platforms and devices your experience can be distributed on - Oculus Rift, Samsung Gear VR, Google Cardboard, etc. Decide which platform(s) you want to release on so you can output different formats at the optimal settings for each. Compression settings depend on the exact device. Perform multiple compression tests to gauge the best settings for each device. If you want to release on Android, there will be many different devices to test. Google Cardboard is the cheapest solution to try VR and you will most likely want to render a version for it as well.

Solutions:

Know your hard(wear).

The Oculus Rift headset is catered more towards gamers and most consumers will be less hardcore. The most accessible way to watch 360 video experience then is with a smartphone, which everyone already has in their pocket. A headset like the Samsung Gear VR will still need to be purchased. Viewers can then mount their Note 4 or Galaxy S6 phone to the headset and use it as a display. Another option is to build a viewfinder out of cardboard! The Google Cardboard can convert any phone including iPhone and other android devices into a viewfinder.

Most phones cannot handle video files over 500 megabytes. Keep your video at the highest quality without overheating a phone or taking days to download.

Currently, users are downloading every experience onto their internal and

external phone disk space. For those who love taking photos and videos, there may not be enough space to store the 360 experiences on the same device. Find a solution to deliver the experience in a reasonable file size without completely degrading the quality.

Check playback of every file on every device you will be releasing the experience on. Make sure to watch the video all the way through. For example, if you are testing a 7 minute video, it might playback smoothly in the beginning. However, the phone cannot handle playback 3 minutes in. There is no way to catch this unless you watched the video start to finish. Do multiple solid tests for the sake of the amount of time and effort spent on the production and for the viewer as well, since bad playback will cause a choppy video which may induce nausea.

PROTIP: Your render may be jittery or not play back on the Gear VR or Google Cardboard if the resolution exceeds 4096x2048. Gear VR currently cannot handle more than 30 FPS as well.

Bitrate Analysis.

There are many ways to optimize the size of the final file with optimal compression.

The software from Winhoros.de analyzes H.264 encoded mp4s. This tool is a free bitrate viewer for PC users only. Mac users can potentially use the Codecian software. Choose your file and let the analyzer run over the length of the video, frame by frame. After the run through, the analyzer will show the average bitrate of the video and a graph over time.

Use this tool to preview which sections of your final file exceed the average bitrate. The file exceeds the average bitrate when there is an above average amount of color depth, resulting in a larger file size. To reduce your file size while keeping overall quality high, compress only the range of frames that exceeds the average bitrate. You can cut your file size in half by even recompressing just 100 frames in a 10,000 frame sequence.

With the bitrate viewer data, you can easily re-encode your final tiff sequence in sections. For example, using FFmpeg, compress sequences of frames around the average bitrate with the -crf option lower and a -maxrate capped at the average bitrate. For sequences of frames exceeding the average bitrate from the analysis, compress them with a higher -crf to lower the quality while keeping your max rate capped at the same average bitrate.

The result will be multiple mp4s compressed with the best settings. Now all that is left is to concatenate the files. Analyze the bitrate of the final mp4 to confirm the average bitrate remains the same.