
making360

Published by ZO, LLC

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First printing, November 2015

Contents

Introduction

What is this book?

2 sections, 57 chapters, loads of fun. problems of shooting and problems of stitching. solutions to those problems. all the techniques to slay all your demons. the book can be read in any random order or end to end cover to cover. however you like. the manual will be free. an open source version will be available for download in pdf format. there will also be a limited edition batch of hardcopy books for those who like to learn the analog way.

Who is this book for?

artists, pioneers, adventurers, astronauts, cowboys and cowgirls; basically anyone who wants to start experimenting on this new medium can join us. we have paved a path and laid stepping stones across this great divide for you to cross the river and join us in exploring a new land! we are sharing every tip and trick we have painfully learned ourselves so you can skip right to having fun. we only ask that you remember to come back and share your findings with everyone so we can build a community!

How to use this book?

How this book is organized?

Why is this book needed

we want to build a community by sharing everything we've learned about making professional 360 videos over the last 3 years. right now, there is very little docu-

mentation on the process, from start to finish, for creating narrative virtual reality films. by writing making360 our goal is to help those who are excited about exploring new storytelling techniques by aiding in skipping the initial hazing process. by sharing our experiences, we will be able to speed up your learning curve. creating 360 videos is very intense and detailed so we're here to walk you through it!

Problems of Shooting

The Elements

Problem:

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

You want to create audiovisual immersive experiences. Expand cinema, compassion, consciousness. 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 dive 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 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

- cameras
- camera rig
- tripod
- audio slate/ring flash
- micro SD cards
- batteries
- usb hub charger
- hard drives
- extra accessories: batteries, micro SD cards, cameras
- courageous heart

- your charming smile

have fun!

千里之行, 始於足下

Platonic Rigs

Problem:

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

6 camera? 7, 10? or 3 cameras with modified fisheye lens? mono or stereo? 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 monoscopic or stereoscopic. This comes down to 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 news 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 get more detail over stereo with 4-8k 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, there will be nadir or zenith hole which may be ok because the viewer will not be looking at the sky or floor most of the time. If you are shooting for a fulldome, the nadir hole won't be a problem. The sky and floor can also be shot with an extra camera so you can capture the information and patch in the nadir hole or replace the tripod in post. 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 fisheye lens. You can achieve a greater fov than wide angle lens and have more coverage per camera. Then 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.

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

MODELS OF THE UNIVERSE ILLUSTRATION HERE

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

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 manually set each camera by hand so decide the default settings you want to shoot 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 framerate.

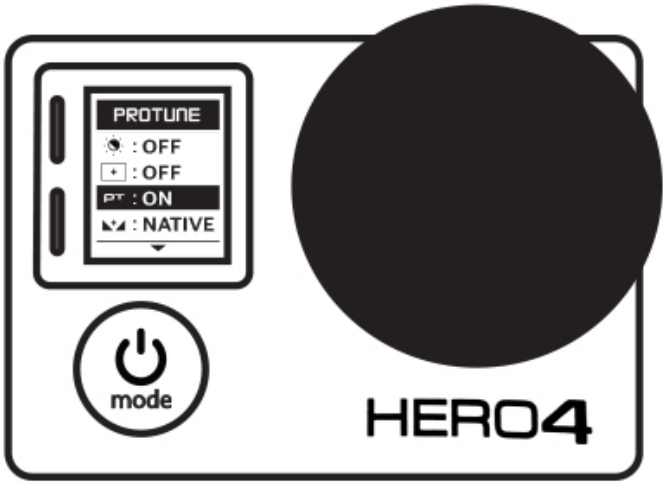
You want your settings matched identically across all the cameras. This will allow them to stitch better and have less color matching and balance to correct in post. Start by deciding the framerate and aspect ratio. This depends on the rig you selected. Certain rigs require a 4:3 aspect ratio instead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

If the cameras accidentally get knocked and the settings change it is ok as long

as the framerate 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. 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 for the stitching software to apply a calibration to.

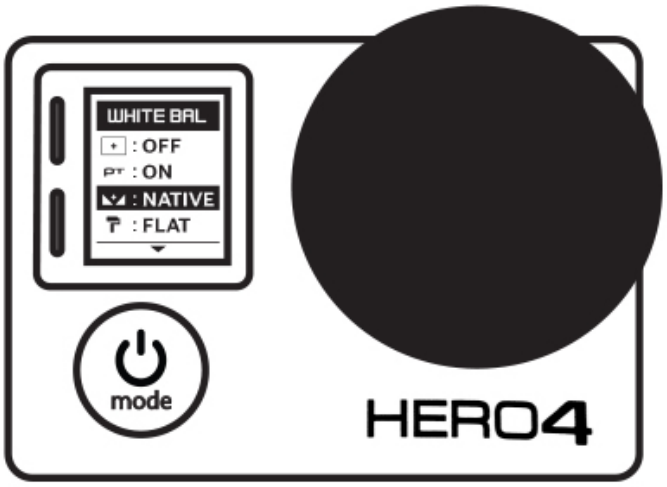
Protune - on



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 mbps) and less compression, giving you more information to work with. Having a neutral color profile across all the cameras will make them easier to color balance and correct for a nice stitch.

PROTIP: Turn protune ON first before you select all the other settings because all the settingsfor resolution and fps reset when protune is changed.

White Balance - cam raw



This keeps the color flat but you keep more information which you can color correct and grade 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.

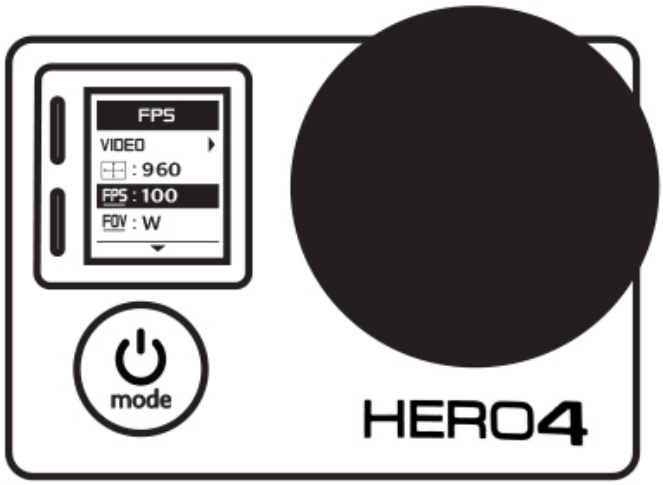
For a hemicube rig like Freedom360, 360 Heros Pro6, or 360Abyss the aspect ratio has to be 4:3 so there is enough overlap in the seams.

The most recent GoPro Hero 4s now offer:

2704x2028 at 30fps

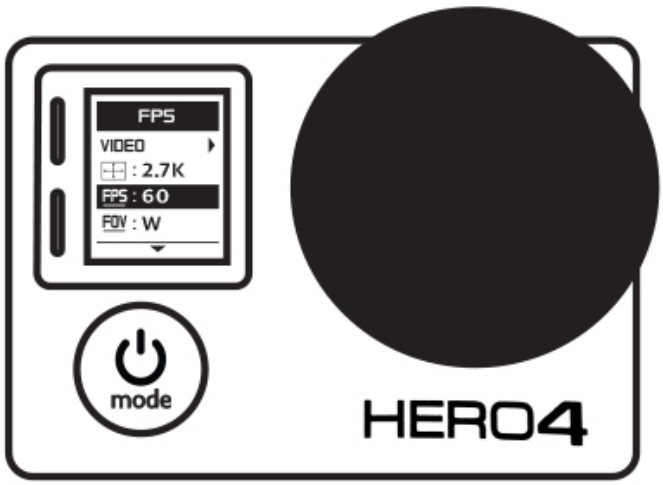
1440x1920 at 80fps

1280x960 at 100fps

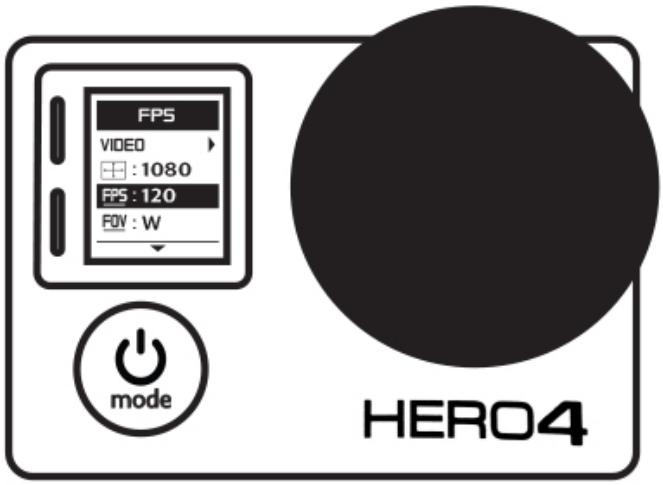


For more cylindrical rigs, the aspect ratio can be 16:9 because each camera will be closer to the adjacent left/right camera.The 16:9 aspect ratio will offer enough overlap. Then you can use the 2.7k settings and have a higher resolution output stitch like 8k.

2704x1520 at 60fps

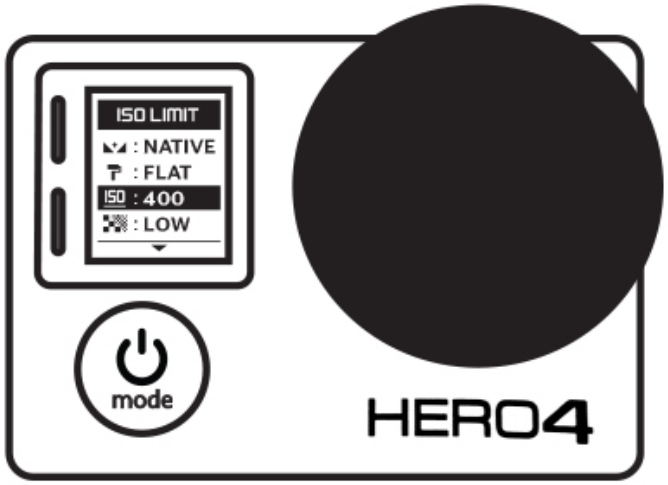


1920x1080 at 120fps



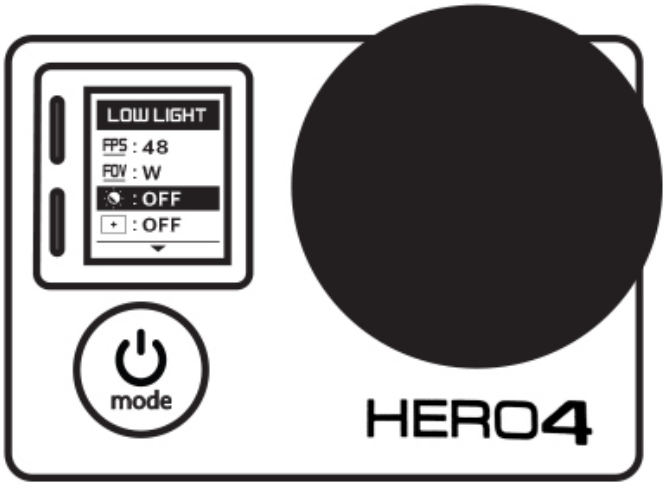
Choosing a higher frame rate will sacrifice resolution. Shoot at a higher fps for fast high action scenarios like drone shots or underwater. Higher frame rate gives more frames to sync the cameras.

ISO limit - 400



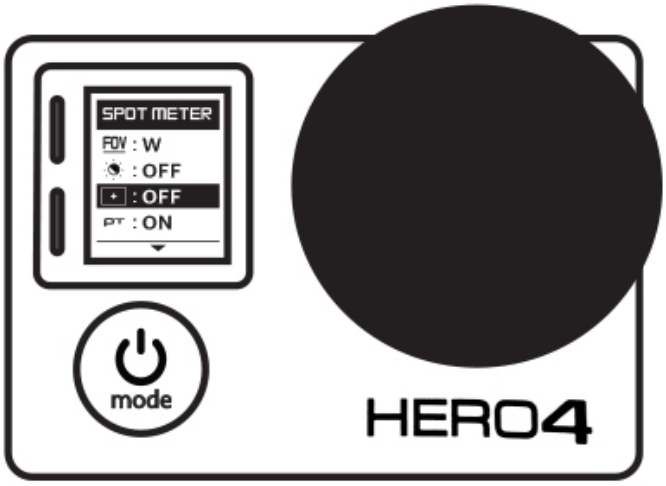
This adjusts the camera's sensitivity in low light conditions. Keep it at 400 which will give you darker videos but the least noise and gain.

Low Light - off

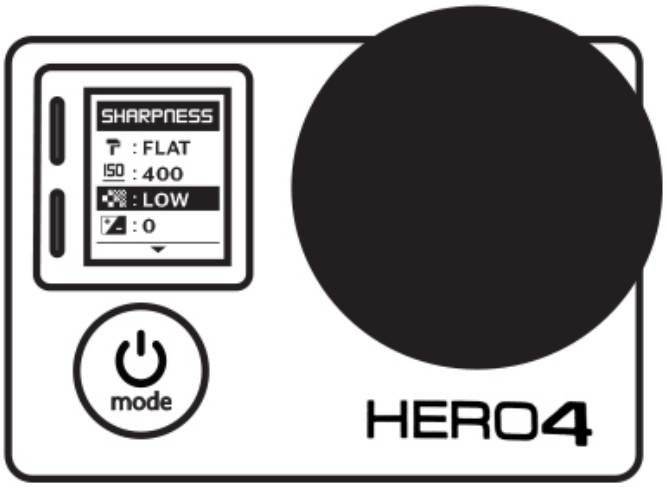


The camera will automatically adjust to changes in exposure when shooting in low light environments. Again, any setting where the cameras are automatically changing we want off so the cameras stay the closest settings to each other.

Spot Meter - off

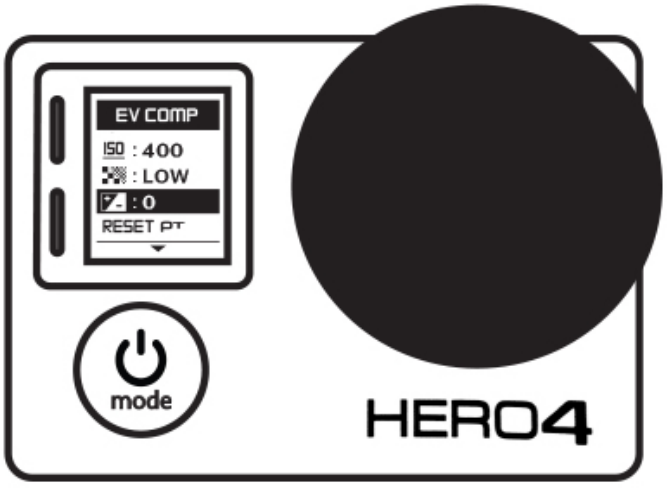


Sharpness - low



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 realtime preview or field monitor

with you, try out and adjust the settings accordingly.

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 to make sure the settings did not accidentally get knocked in transit.

Problems of Stitching

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 ingesting 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 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:

Organizing a project folder

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 video from each camera folder into a new take folder (ex. Take 1). Here's a snapshot of how it looks before and after.

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 eye. 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 a case of stereoscopic projects.

For example,

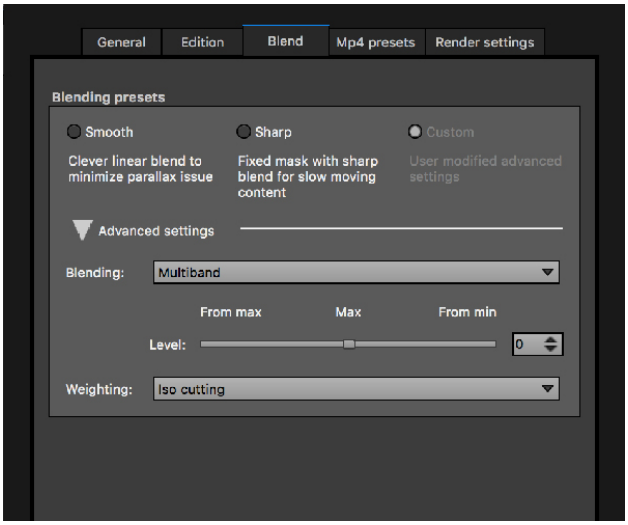
GOPR02355 would be T01_HD_C01_GOPR02355.mp4 for a monoscopic project.

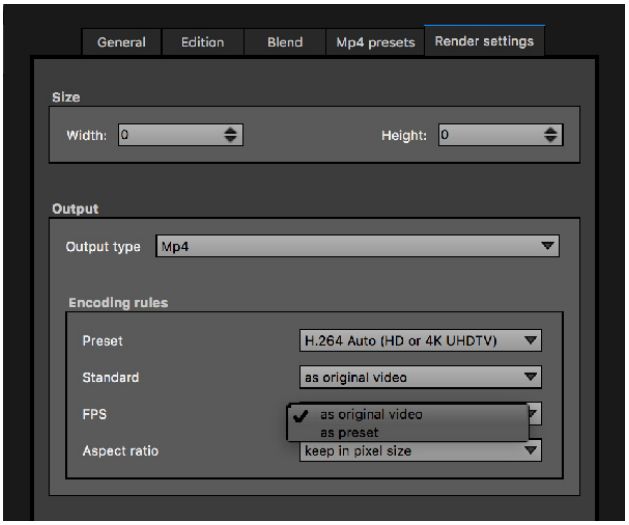
GOPR01025 would be T07_4K_C03_LE_GOPR01025.mp4 for a stereoscopic project.

Quick stitching of takes

To combine the individual videos into a single high resolution seamless panoramic video, you will have to "stitch" them together. Most video camera manufacturers are developing built-in functionality to ease the stitching/playback of 360 dailies. If you don't have a real-time stitching 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.

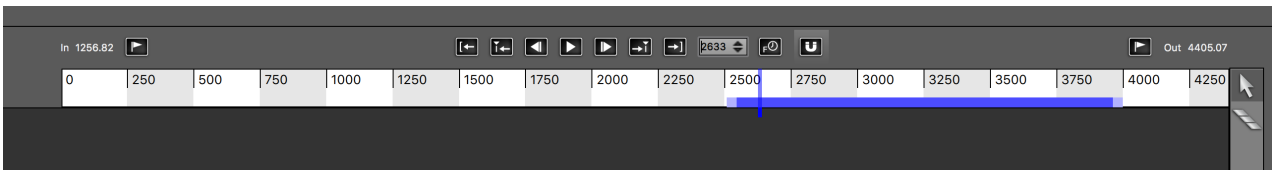
Open the "preferences" of AVP. Under Blend > set Blending Level to 0, Weighting to ISO Cutting, and under Render settings > set FPS as original video.



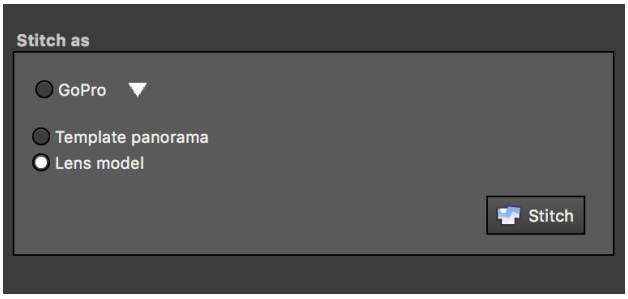


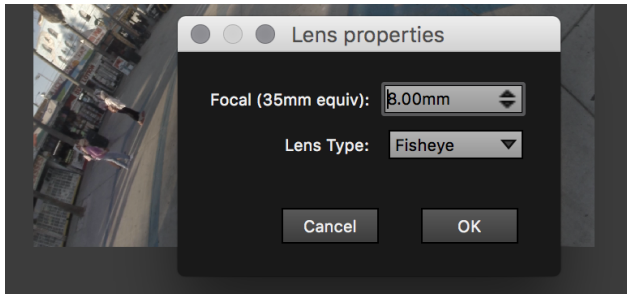
Drag your videos into AVP. All videos must have the same length, same format (mp4 or mov) and same frames per second (fps). The accuracy of the visual sync between cameras may vary depending on the equipment used, or your **Set and Settings**. Ensure all cameras are perfectly synchronized before stitching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

Before jumping onto the stitch tab (fourth icon in the AVP header bar), select a range of frames by trimming your timeline at beginning and end using the blue range selector. 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.

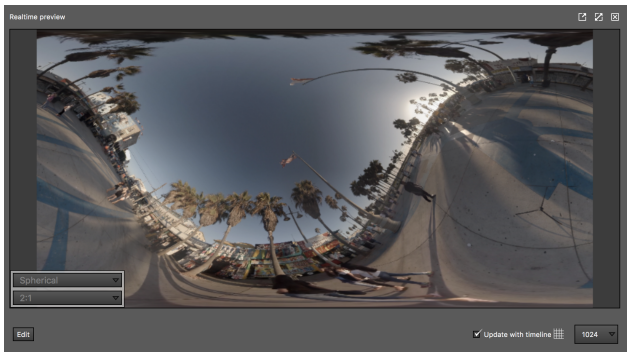


Select a stitching preset using the dropdown. The default preset will auto stitch as GoPro. If you are using different camera lens, check "Lens model" and input the focal length and lens type. For example, enter in 8mm for your focal length and fisheye for type of lens. Press "OK", then click "Stitch"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





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.



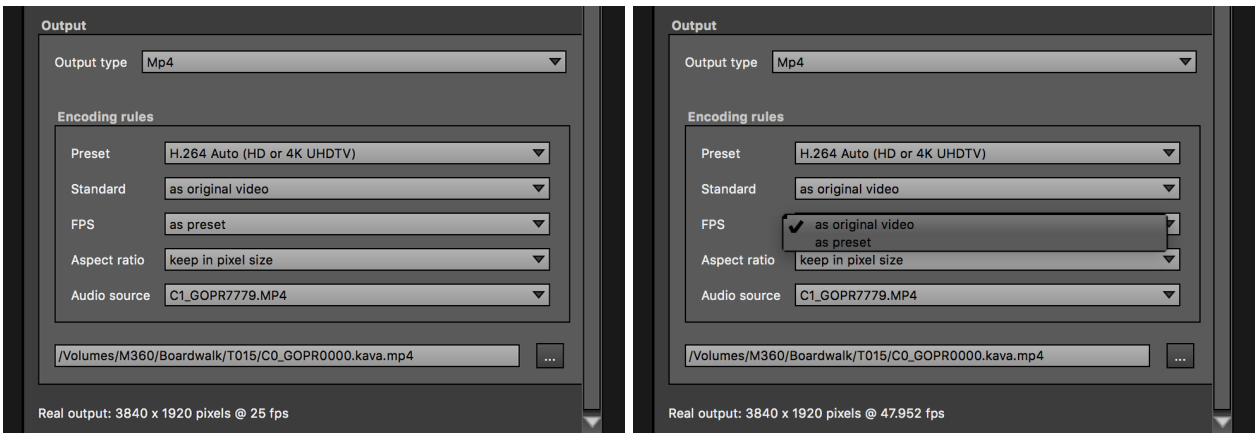
Bravo, you have just completed your first quick stitch, now you are ready to render your work!

Rendering your work

Rendering is the last step in any workflow. Every software you use to edit the picture 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.

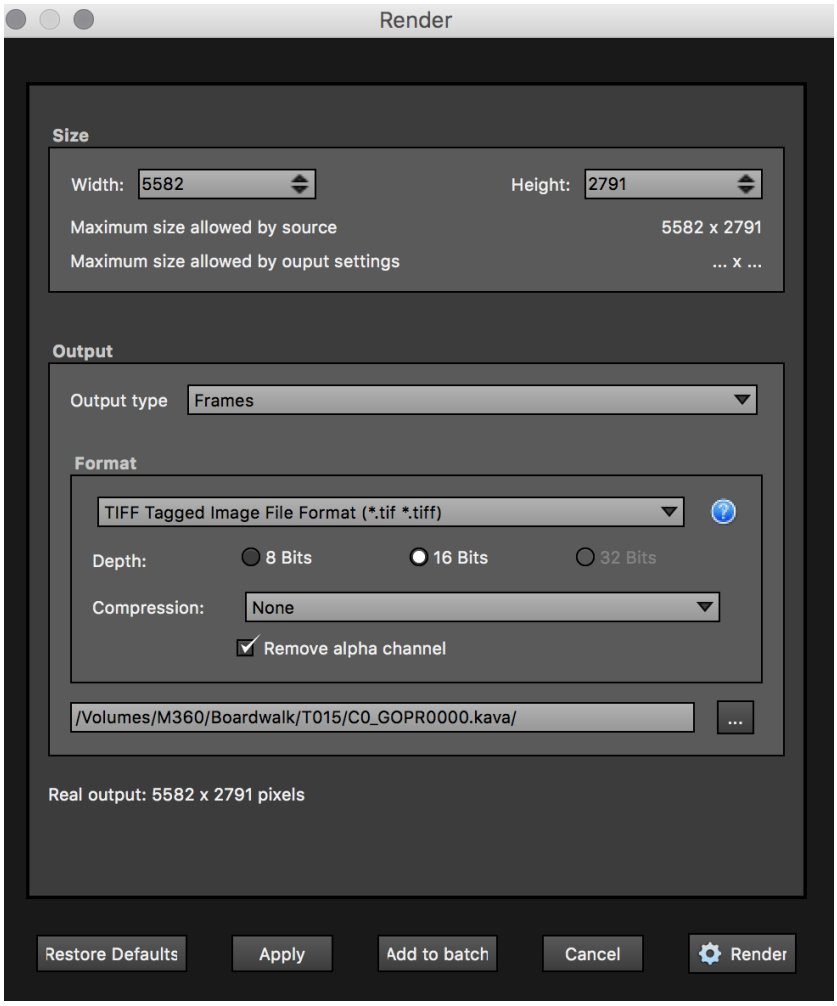
Before you start rendering, double check that all your default preferences are correct. Consider the right fps for the playback solution of your choosing. Even if you shot at 100fps or 60fps, you will want to output at an FPS that the headsets or video player can handle.

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, I generally like to set my 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 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 8k. 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 GearVR, render your videos at 3840x1920 or 4096x2048 when shooting 4k (1920x960 is SD).

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. You will want to render frames to keep the highest resolution of your panorama and 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: h264 mp4 maximum height at 2304px). Rendering tiff sequences will allow you to keep the maximum output resolution and quality. 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. You will want to work and keep the files with at highest resolution and quality, starting with AVP. Output TIFF Frames at 16 bit, and No compression in AVP.



PROTIP: Removing 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 time-code or you can do it...the "hard" way aka not really, just geeky but in reality faster way! **Hello FFmpeg** Don't let the terminal or command lines scare you!

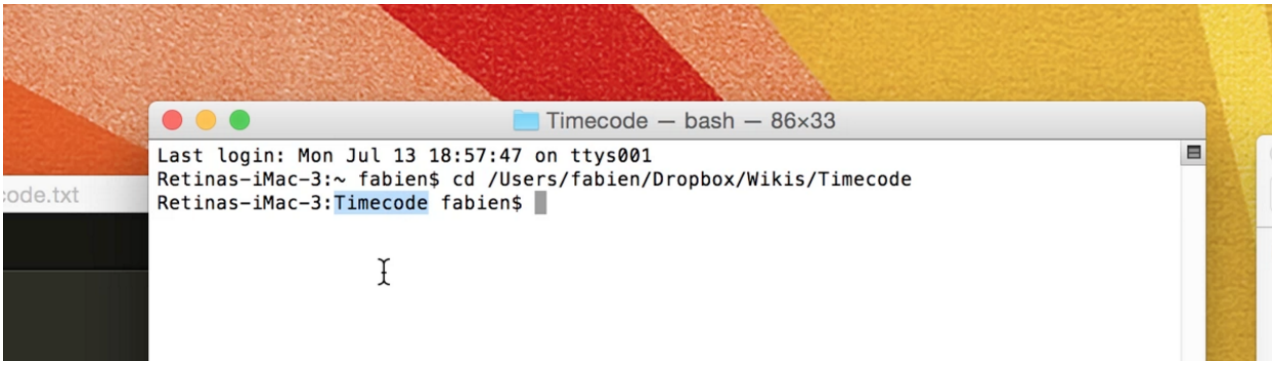
For Mac users, the "drawtext" filter of FFmpeg is only working with this FFmpeg library. Unzip the 7zip file using Keka, then place the 30mb "ffmpeg" file in the directory where all the libraries live, usually /usr/local/bin/ffmpeg.

Show/Hide Hidden Folders and Files on Mac:

defaults write com.apple.finder AppleShowAllFiles YES

defaults write com.apple.finder AppleShowAllFiles NO

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



PROTIP: If your Finder is opened with your video visible, drag the folder icon into the Terminal window AFTER typing "cd" (e.g. change directory).

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 framerate as video.

Run FFmpeg by simply the 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 framerate (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!

First Assembly

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

Jack Kerouac, Belief and Technique for Modern Prose

Problem:

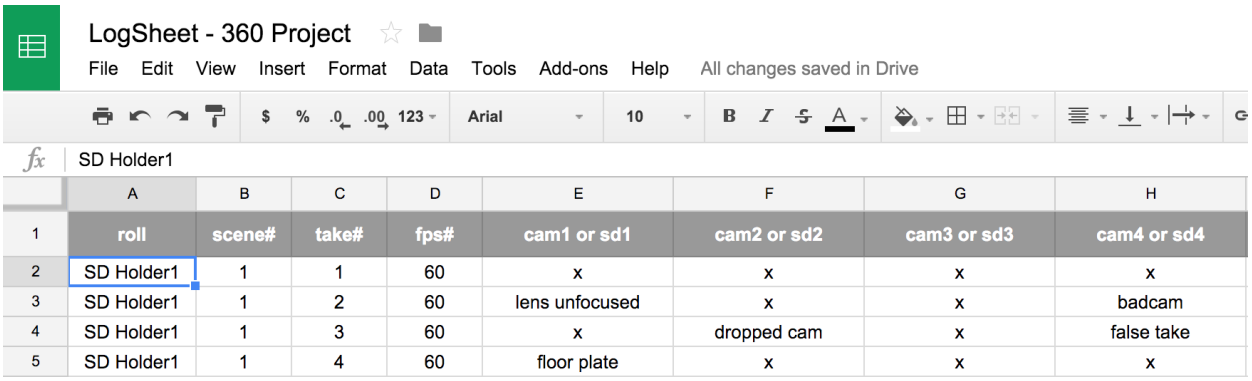
You need to assemble a rough cut with multiple unstitched video streams.

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 materials, 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 tart 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

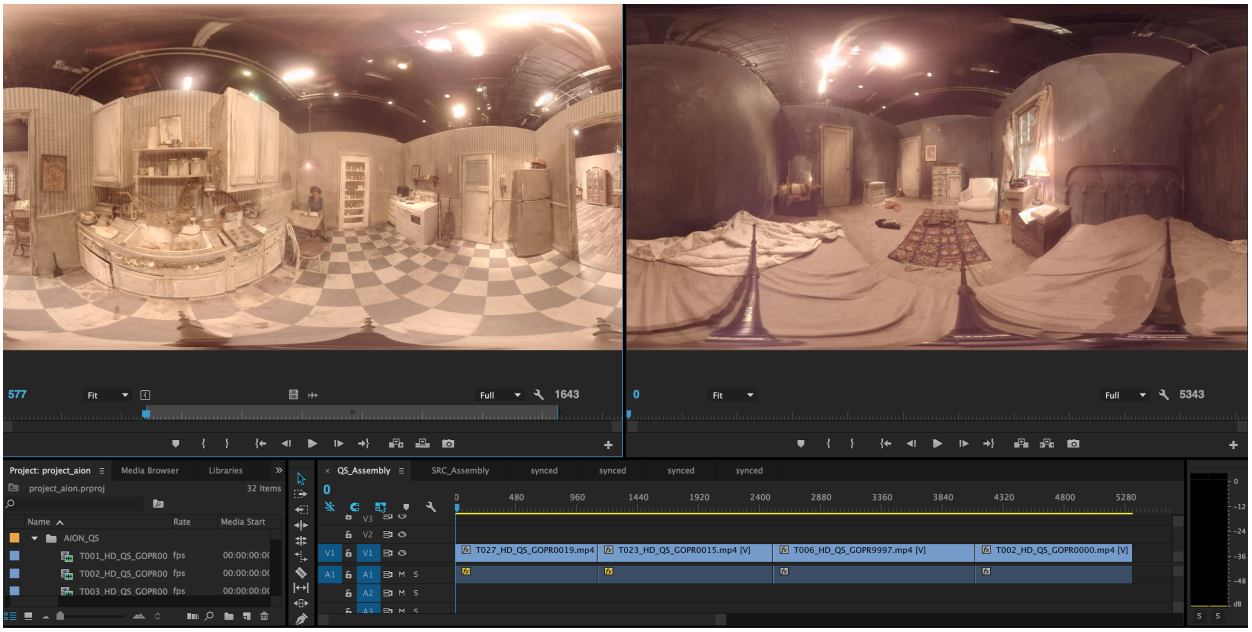
The goal of the log sheet is to track the INs and OUTs of all your selects, the cameras that need some exposure correction, the synchronization offsets, the location of files and all notes from the team. The log sheet will be extremely helpful for the stitcher, editor, and director.

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 of your rig.

First, use the quickstitches to build an edit. This method is similar to the traditional rough cut edit. Bring all your quick stitches into Premiere, use the shortcut I for IN and O for OUT to reflect the log note’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.

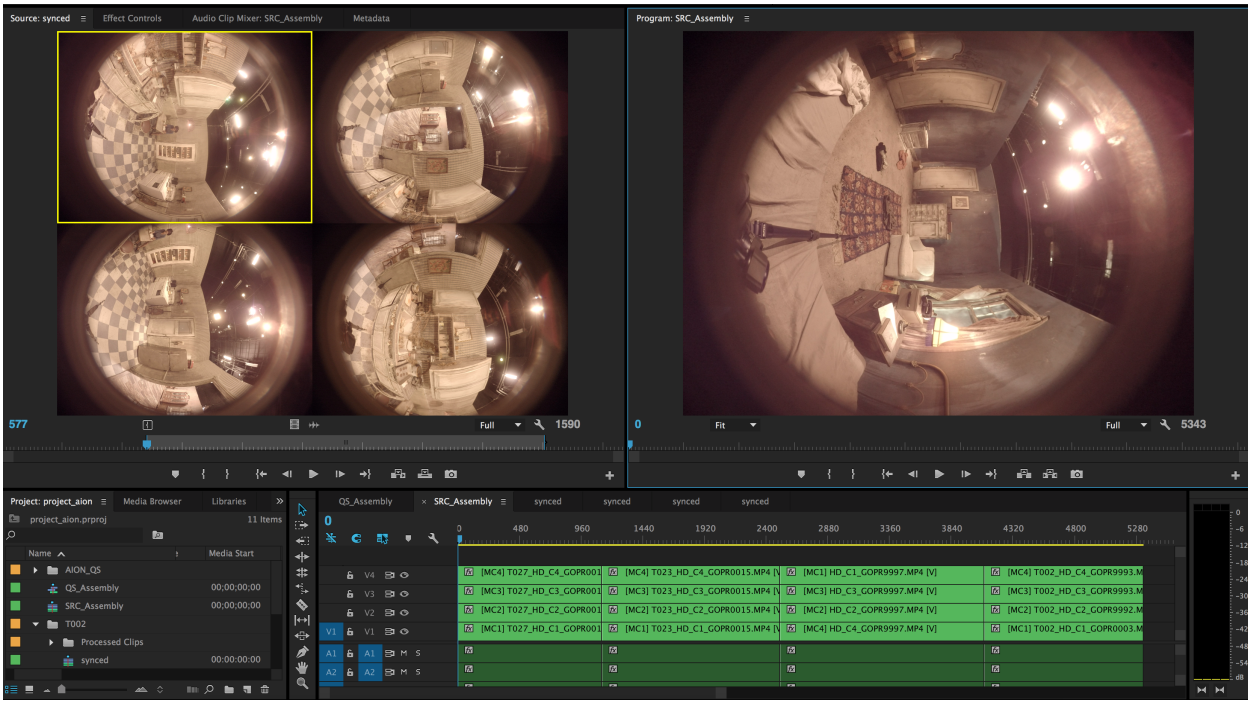
When assembling all clips in your timeline, focus on the timing of the transitions. Give the viewer enough time to adjust to the new scene. Then edit all your best clips into the order you desire. When satisfied with the first assembly of the quick-stitches, render a low resolution preview of it or start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



Assembling with source footage will require one video track per camera and should match precisely 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 INs and OUTs points of your log sheet and assemble them like the previous 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 purpose, 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.

Color Matching

Problem:

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

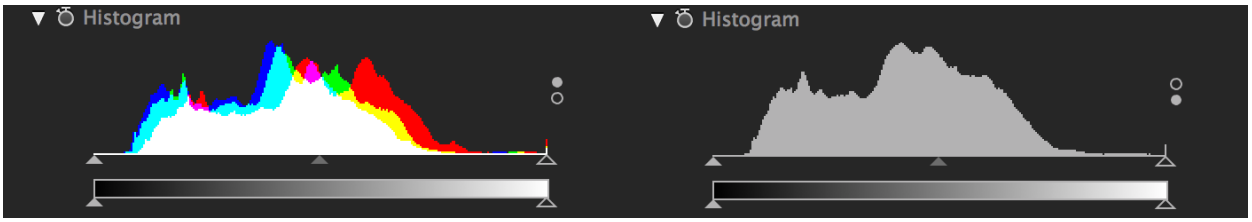
Pure white reflects 100% of the light, while pure black reflects 0% of the light. Any camera's metering system wants to meter everything as middle gray, usually around 18% gray. Exposure compensation is a challenge during production, as it reflects 18% of the light that is cast upon it. This is an even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

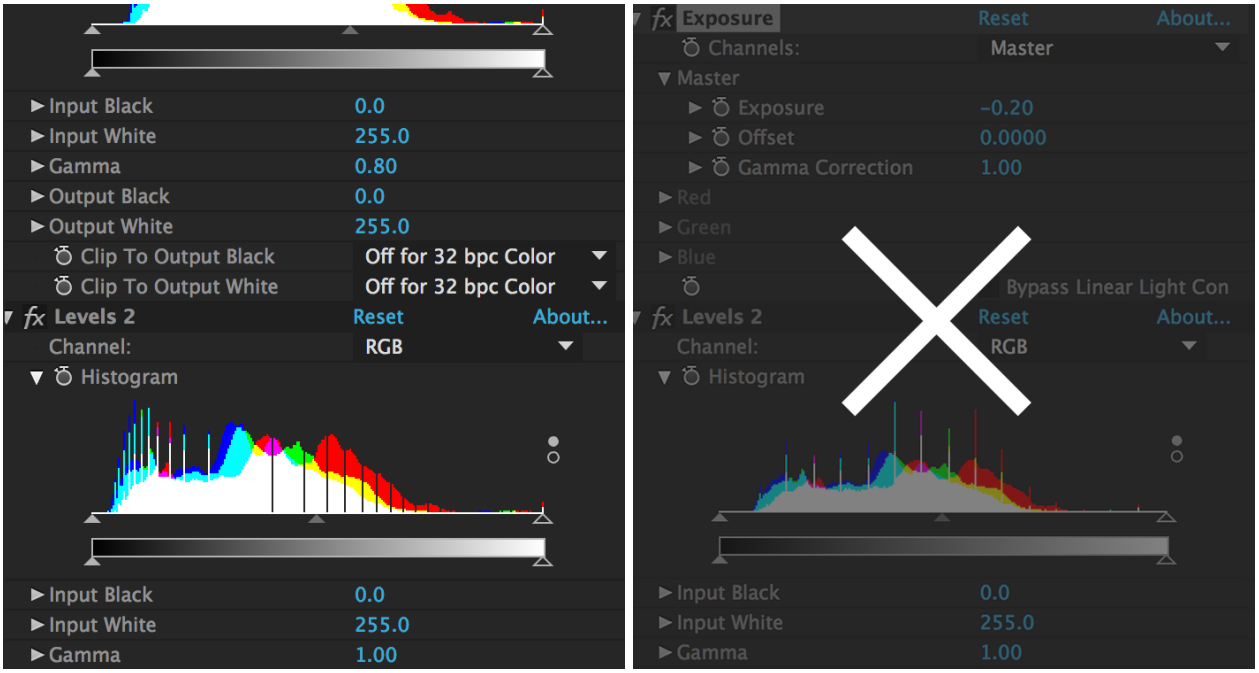
There are two histograms. The main color histogram shows the red, green and blue channels (the actual real data) and the one channel combined value histogram is only a simulated computed value called luminosity. Use the color histogram or select an individual channel to adjust instead of the combined 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 third 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 an audio or motion signal recorded at the start of the take during the shoot. 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 cameras got dropped, there was no speedlight for 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 leg's 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 a motion

flash or speedlight during production. Select the nearest frame and a range for AVP to auto-detect the flash 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 quick stitches 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 synched and ready for stitch.

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 and 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 176 frames.

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

For example:

Cam1: Start Frame = 0; Offset = 176 - 0 = 176 Cam2: Start Frame = 106; Offset = 176 - 105 = 71 Cam3: Start Frame = 64; Offset = 176 - 64 = 112 Cam4: Start Frame = 176; Offset = 176 - 176 = 0

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.

IMAGE

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 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 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.

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 point 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 rectangle 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 up 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 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. You will notice that 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 Points, instead of the Patching Nadir method. Parallax also creates stitching tricks and advantages such as hiding a Monopod in the parallax zone.

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 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 masker 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 bottom left of 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 adding 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 consequences 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.

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

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 quick changes, almost done! You preview just a few seconds and one or two seams just showed up out of nowhere. Should you have 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 Quickstitches.

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 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 Points 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 efforts 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 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 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.

This technique applies specifically to camera rig solutions that use 3 or 4 modified fisheye lens.

With modified fisheye lenses, subjects can get closer to the cameras because the fov for each camera is even wider. The subject will be able to get close to camera without breaking a seamline. There is also more overlap between each camera, IMAGE allowing you to move the seams with masking markers or rotoscoping. 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 masking or rotoscoping.

Check and uncheck some of your cameras in APG by using the group layers at the bottom of the window. IMAGE 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 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 two hidden cameras camera. IMAGE Use the red ‘remove’ markers to delete extra information you don’t need.

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 has 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 Points

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. 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 is fully in, the other where the subject is 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 subject in the second image. The subject will be kept in the first image and the half cut subject will be completely removed. Preview the result to check.

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 2nd green marker (on whole stack) and move the mouse over the object to keep. Make sure the right 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.

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.

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. 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 lens are 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 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. IMAGE

If you want to shoot with subjects extremely close to the camera, fisheye lens are the way to go. However, fisheye lens produce fuzzy edges around the lens and traces of lens flares or blueish light around the image. Autopano blends some of these artifacts 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.

IMAGE

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. IMAGE As you can see, every single lens is different, even when the same make and model. Their centers will 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.

Dolly 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, revealing the spontaneous manifestations of daily life, shooting without any camera movement may be boring. 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 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.

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, section by section. Update the timeline with changes from APG to AVP. IMAGE

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. IMAGE Now re-stitch and optimize each each section by selecting its state. Restart the RMS analysis to see the improvements in updated values.

Lastly, Patch the nadir for large dollies that covered the ground floor. Expensive motorized dollies are a great luxury but comes 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. Download the 360 viewer Kolor Eyes.

Open the application and drag your stitched mp4 or mov into the Kolor Eyes window. Use your mouse cursor to rotate and check for seams and any areas that require cleanup.

Kolor eyes to Oculus Rift DK1 or DK2.

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

Download Oculus Runtime for Win or Mac (FYI: no longer supported for 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 bottom of the window. Click on it and check in the Rift if your video is showing. The Rift's headtracker 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 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 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.

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 GearVR 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 most process and distort your colors, decreasing the potential for highest quality picture. Your eyes may not be able to see, look at the changes in color median, the mean of RGB histograms, and number of colors. 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 risks 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 your framerate (fps) to match the framerate or your videos, generally 29.97 for NTSC players. Then change the color bit depth to 16 bits per channel. You can also update the default FPS under the Import Preferences.

Import the tiff sequences rendered from Autopano and rename 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. IMAGE

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. The same 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 the nadir and fixing seams via Rotoscoping or Masking.

IMAGE 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. Sstart 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.
- Select all comps + Render made my life easier than Menu>Composition>Render for each comp, especially when you have 100 comps to render.
- 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.

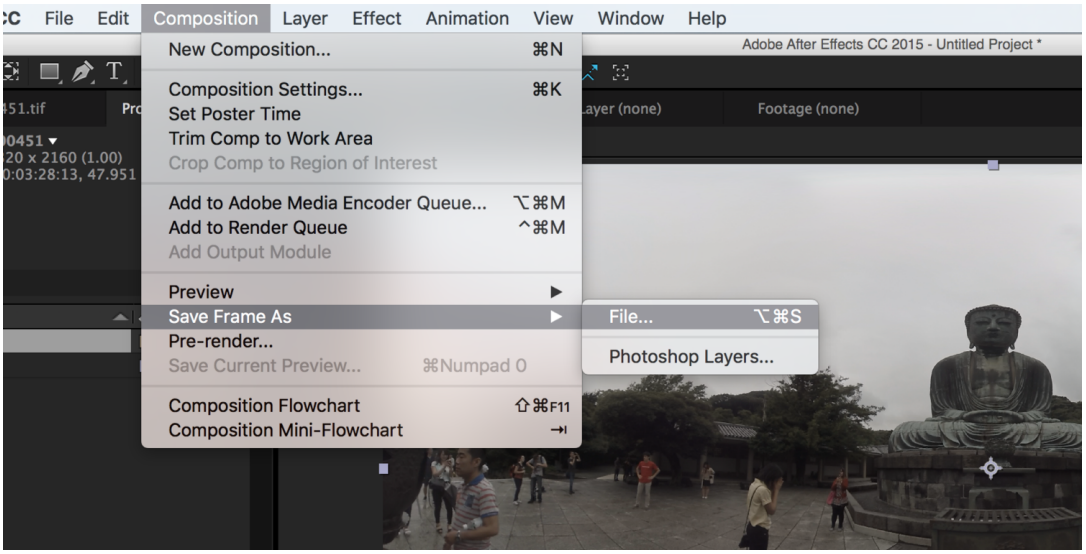
You have stitched your videos but the tripod still shows. You didn't shoot the moon to replace the camera rig and Autopano does not recreate missing pixels. When you try using the red masking markers to hide the rig, some weird blending or a black hole is generated in the panorama.

Solution:

Use Photoshop's clone stamp to recreate missing pixels.

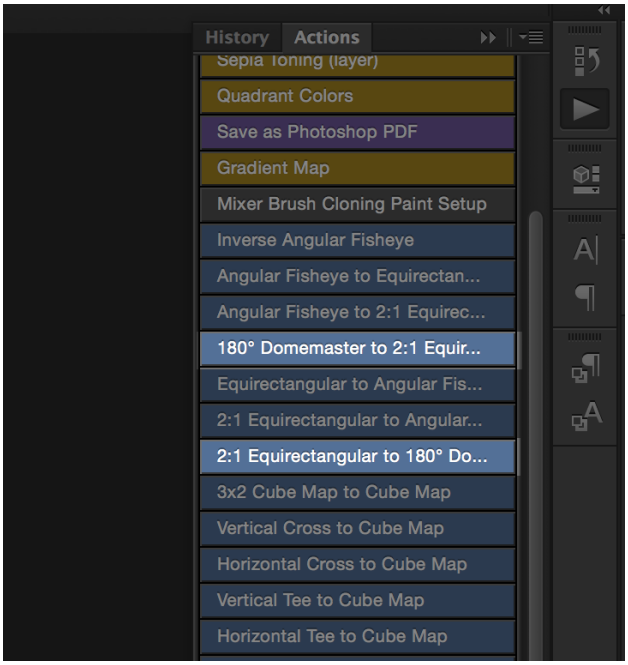
Flip the panorama vertically to edit the desired area. Then convert your 2:1 Equirectangular panorama to 180° Fisheye / Domemaster format. After editing the nadir or zenith in Photoshop, convert back to 2:1 format and flip if needed to flatten the panorama.

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.

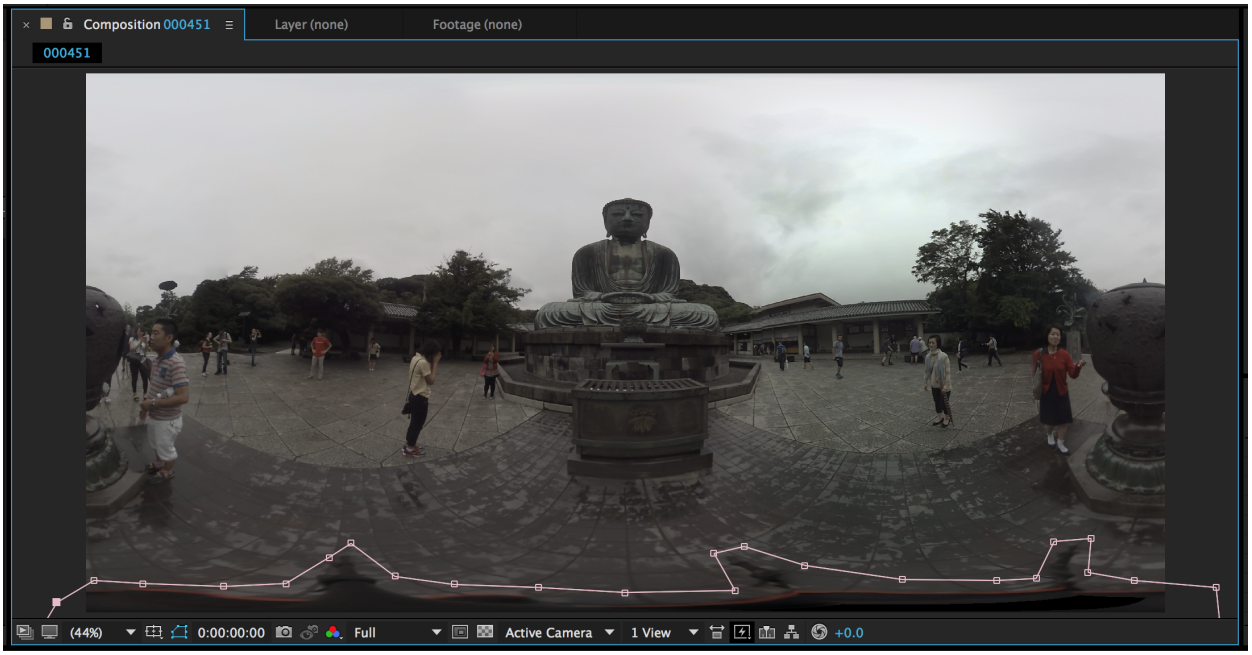


In the Actions list, select 2:1 equirectangular to angular fisheye or 180 domemaster. The panorama format is now converted to a planetarium view. Edit the tripod here using the stamp tool.

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 After Effects, 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 different time.

You shot different angles or different content with same angle using one GoPro or RED Dragon camera. You can’t synchronize 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. Next, blend the angles or create overlapping areas over your source footage in AE to utilize Autopano’s blending algorithm.

IMAGE

In this case, there are 4 angles with same subject in each angle doing different things. Edit each angle in Premiere just like 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 Points 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 tiff sequence.

In AE, import both sequences under their take folder and create a new composition 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 with 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 over a static shot to create a mask is the fastest way to composite an object into your panorama. For moving shots, motion track using a null object first and link your mask to it or Rotoscope 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 the architecture of the distant background that contains the object or subject to hide unfixed seams in AVP. Sometimes, it is just enough and 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 wrap 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 fish-eye 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 Dailies Quickstitches, you need to preview every piece of 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. You can render a tiff sequence of this title from AVP and add it 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 is difficult, time intensive work. Detail to attention on the sync is required if you plan on animating a keyed object from the sky to wrap all around you and then onto the floor. 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 or with the same 360 rig. Shooting with the same 360 rig makes the job a lot easier. With any green screen footage, defish and reproject onto a sphere.

Import your footage along with a black video with the same camera configuration. Then click Edit to open APG. Uncheck the black video layer to render only the green screen with the right warping for a latlong 360x180. Under preview, set all blending and weighting to None. If necessary, use the Circular Crop to scale your video up. You can also set all image properties to 0 to center your video 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.

When finished, place your keyed object of the subject 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.

AE Polar Coordinates.

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.

Here's an easy After Effects method, similar to Patching Nadir, to handle some types of VFX and keyed object compositing. Create a square composition that is equivalent to the width of the panorama, for example, 3840. Every asset that needs to be keyed will be handled in this composition.

Bring the composition into the panoramic 2:1 composition, with its dimensions of 3840 x 1920. Add the Polar Coordinates onto the square composition. Then transform this square comp to fit in 50% of the 2:1 comp, either position on the upper half or lower half. This will allow you to control animations for half the screen. For this example, scale the height to 25% and position of height to 960/2. Then change the Interpolation value of the Polar Coordinates plugin to 100%, with Polar to Rect conversion selected.

Now, animate everything in the square precomp and the projection will update itself in the main panorama.

Hello FFmpeg

Problem:

You need a tool for compression.

??????

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 only)

FFmpeg has always been a very experimental and developer-driven project. New features are added constantly and after installing it on PC and Mac, I realized the main build of ffmpeg didn't have the needed filter nor was able to endode videos using the h265 codec.

The right binary to install on Mac is the version 2.7.2 built by Helmut Tessarek. Unfortunately, it is compressed with 7-zip, so you may need to get a decompressor first. I used Keka (not open source, but free).

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

You will need to place the unzipped FFmpeg binary, which should be a 30mb file, into the shared among users 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, you can create it and it will work. You will be asked to authenticate by inputting your password.

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

Convert Files

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

```
ffmpeg —i video.mov video.mp4
```

Now let's convert a tiff sequence into an .mp4 file. You will first need to replace the logical order of your tiff numbers with _05%d 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_05%d.tiff —r 25 sequence.mp4
```

Concatenate Sequences

If you're recording high definition video on a GoPro HERO4 Black, for instance, you're going to fill up 4GB pretty quickly. In some video modes, it's as quickly as 8 minutes and 52 seconds. If you're using smaller or lower quality settings, you'll get more footage before you hit that 4GB threshold. That's why GoPro breaks its videos

up. Once you get to 4GB, it'll tie off that segment and start a new one. Once that new one gets to 4GB, it'll start another. And so on, until you stop the recording, the card fills up, or your battery runs out.

Use FFmpeg to concatenate your sequences, it'll go much faster than using a video software's rendering engine.

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_05%d.tiff -i audio.mp3 -codec copy -shortest output.mp4
```

When you need to add multiple audio tracks to a video, for later use with head tracking for example, 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.

H264 vs H265

Apple's current preferred compression format, H264, has been a huge success as being 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 H265 enabled binary:

H264:

ffmpeg −r 29.97 −i sequence_05%d.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 H265, options are passed to x265 with the -x265-params argument such as:

ffmpeg −r 29.97 −i sequence_05%d.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.

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 sake of the amount of time and effort spent on the production.

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 30fps as well.

Bitrate Analysis.

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

The software from Winhoros.de analyses h264 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 very final mp4 to confirm the average bitrate remains the same.