
making360

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# 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

# 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.

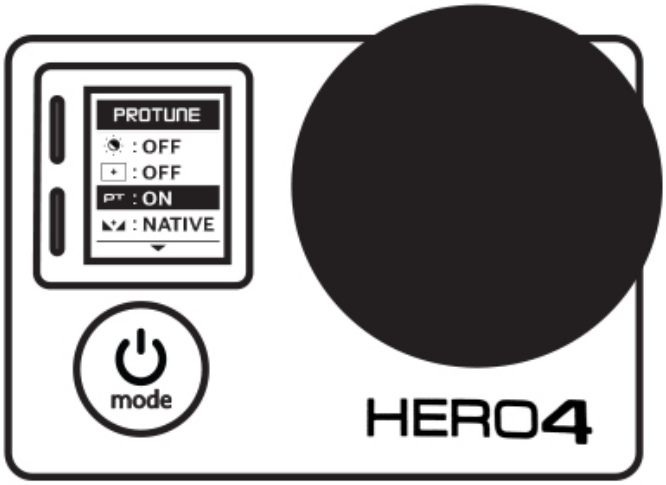
You want your settings matched identically across all the cameras. This will allow them to stitch better and have less color matching and balance to correct in post. Start by deciding the framerate and aspect ratio. This depends on the rig you selected. Certain rigs require a 4:3 aspect ratio instead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

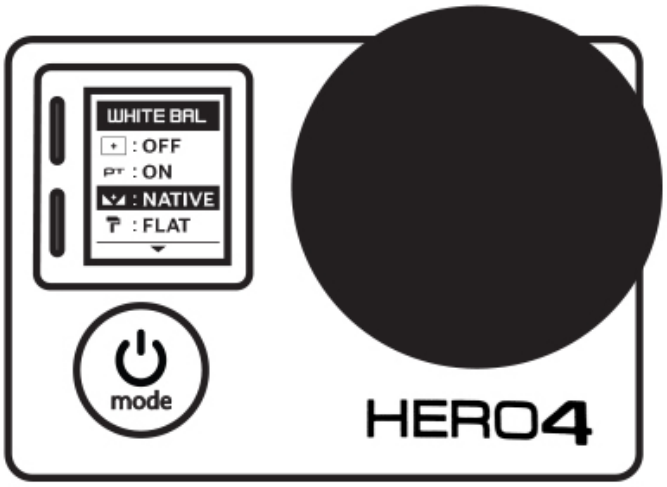
## Protune - on




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.

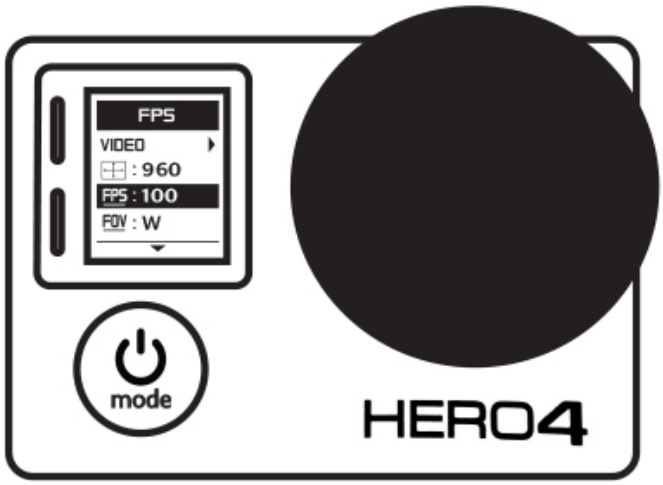
For a hemicube rig like Freedom360, 360 Heros Pro6, or 360Abyss the aspect ratio has to be 4:3 so there is enough overlap in the seams.

The most recent GoPro Hero 4s now offer:

2704x2028 at 30fps

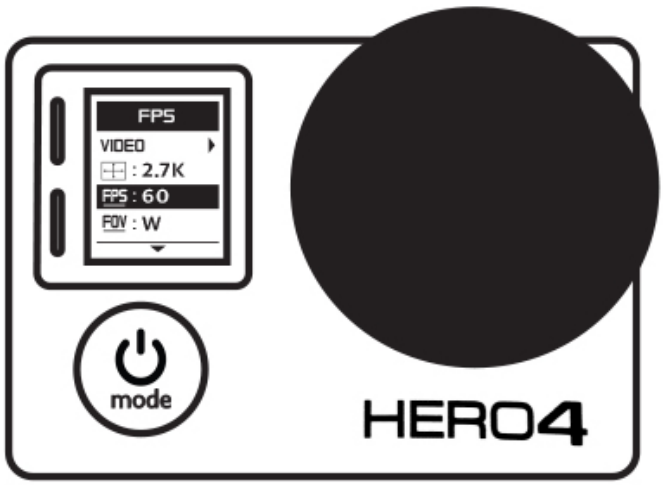
1440x1920 at 80fps

1280x960 at 100fps

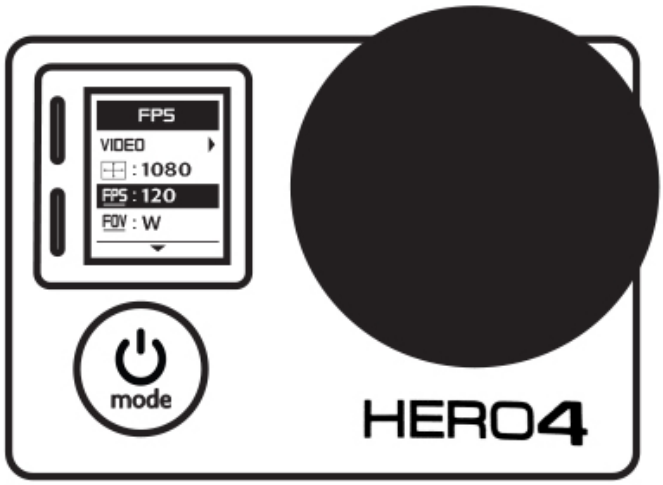



For more cylindrical rigs, the aspect ratio can be 16:9 because each camera will be closer to the adjacent left/right camera.The 16:9 aspect ratio will offer enough overlap. Then you can use the 2.7k settings and have a higher resolution output stitch like 8k.

2704x1520 at 60fps

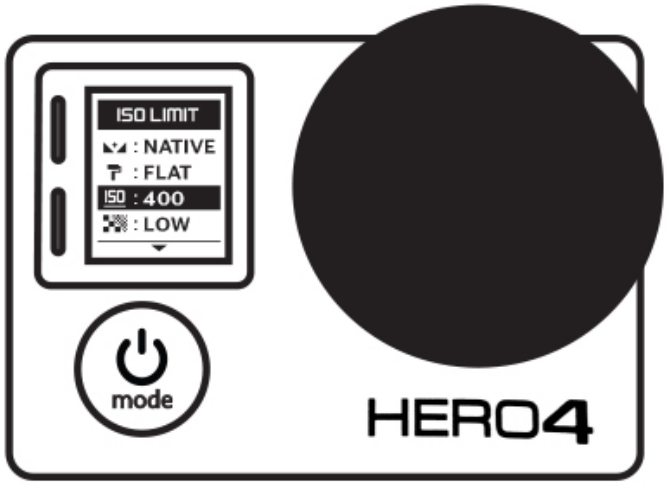


1920x1080 at 120fps



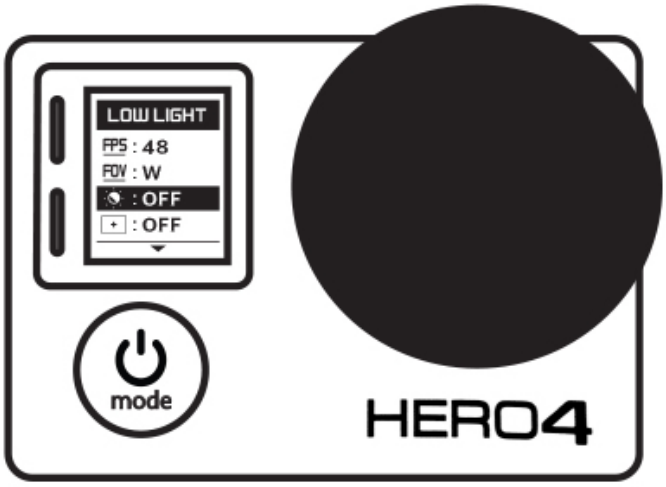

Choosing a higher frame rate will sacrifice resolution. Shoot at a higher fps for fast high action scenarios like drone shots or underwater. Higher frame rate gives more frames to sync the cameras.

## ISO limit - 400



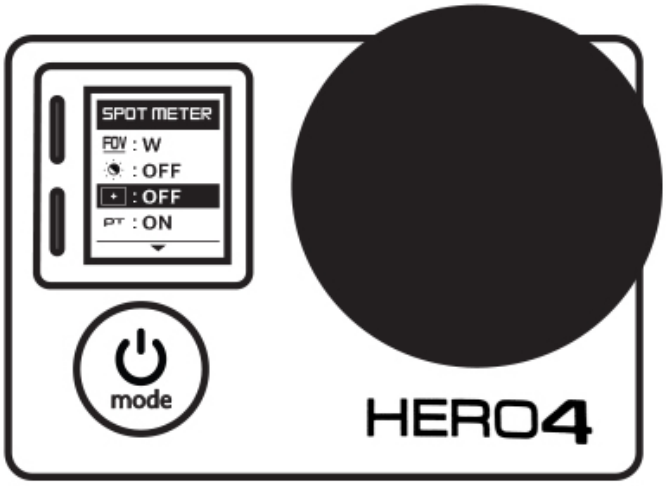

This adjusts the camera's sensitivity in low light conditions. Keep it at 400 which will give you darker videos but the least noise and gain.

## Low Light - off

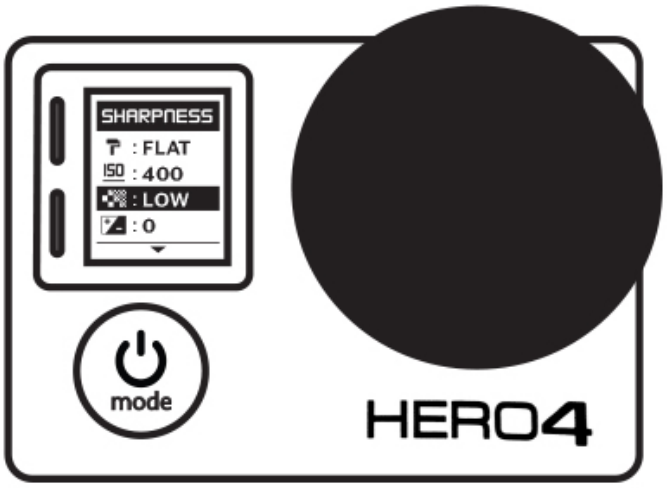



The camera will automatically adjust to changes in exposure when shooting in low light environments. Again, any setting where the cameras are automatically changing we want off so the cameras stay the closest settings to each other.

## Spot Meter - off

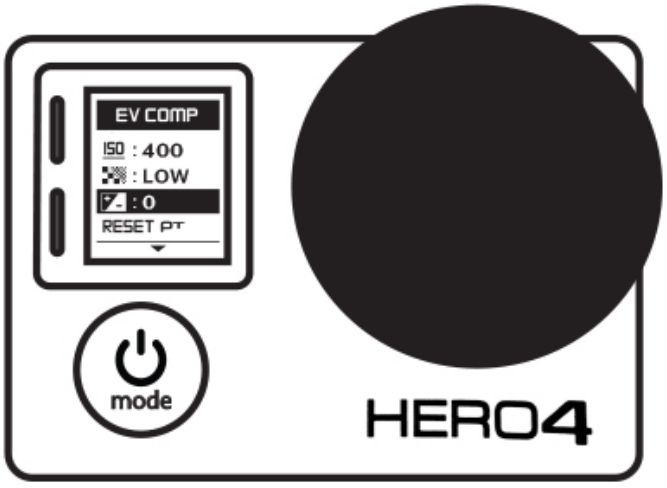


## Sharpness - low




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 is 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,

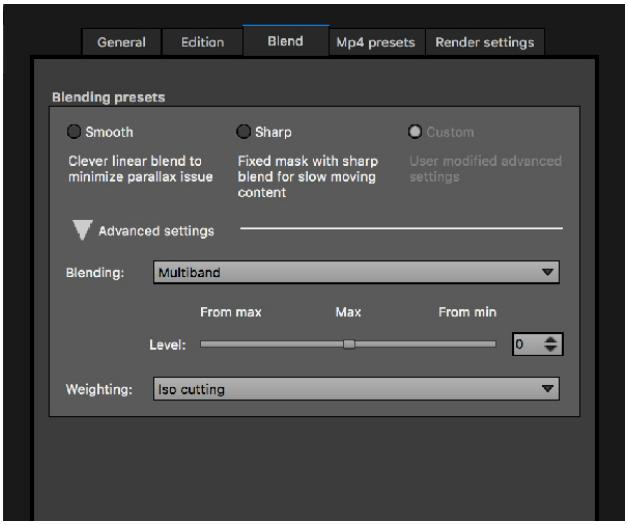
GOPR02355 would be T01_HD_C01_GOPR02355.mp4 for a monoscopic project.

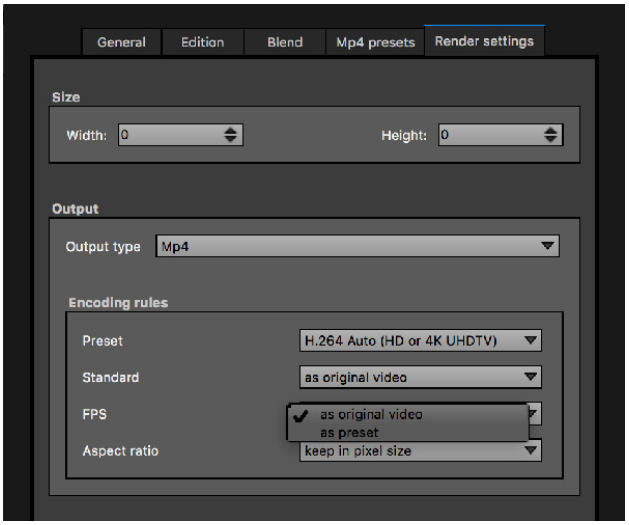
GOPR01025 would be T07_4K_C03_LE_GOPR01025.mp4 for a stereoscopic project.

## 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.

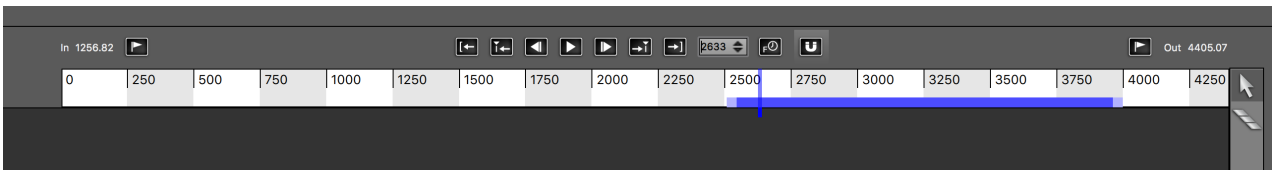
Open the "preferences" of AVP (or command + ,). Under Blend > set Blending Level to 0, Weighting to ISO Cutting, and Render settings FPS as original video.



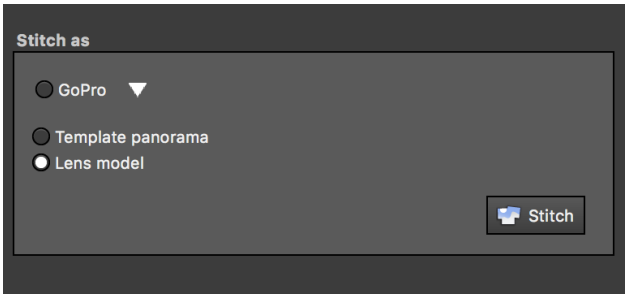



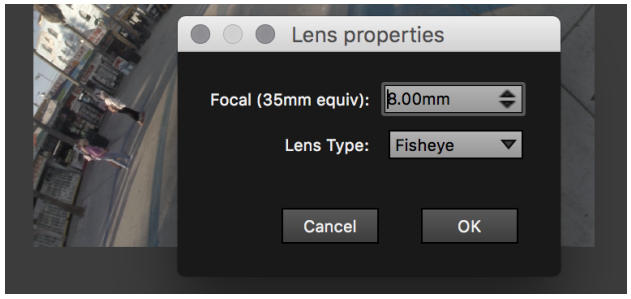

Drag your videos into AVP. All videos must have the same length, same format (mp4 or mov) and same frames per second (fps). The accuracy of the visual sync between cameras may vary depending on the equipment used, or your set and settings. Ensure all cameras are perfectly synchronized before stitching (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.

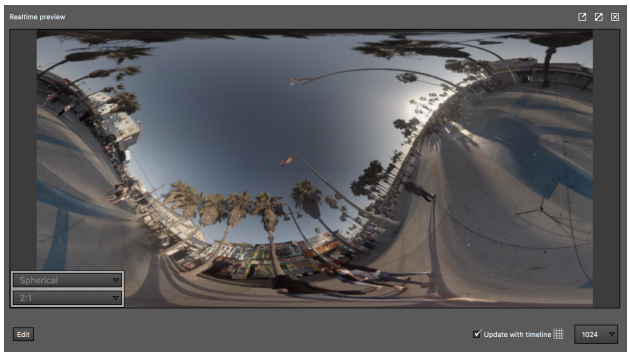


Select a stitching preset using the dropdown. The default preset will auto stitch as GoPro. If you are using different camera lens, check "Lens model" and input the focal length and lens type. For example, enter in 8mm for your focal length and fisheye for type of lens. Press "OK" and then click "Stitch"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





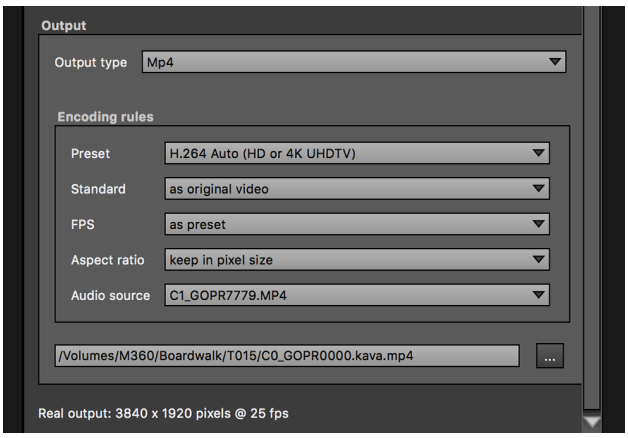
Bravo, you have just completed your first quick stitch, now you are ready to render your work!

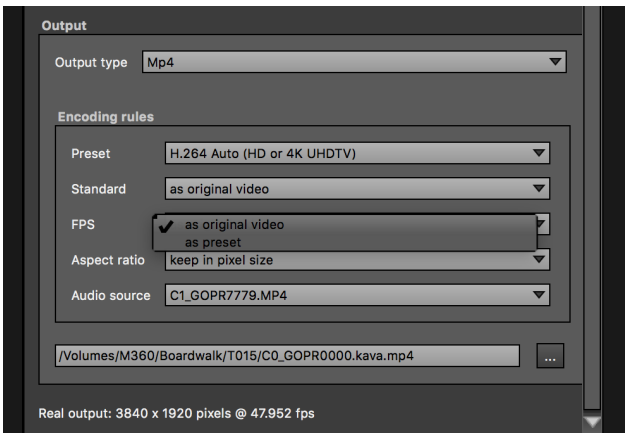
## Rendering your work

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.

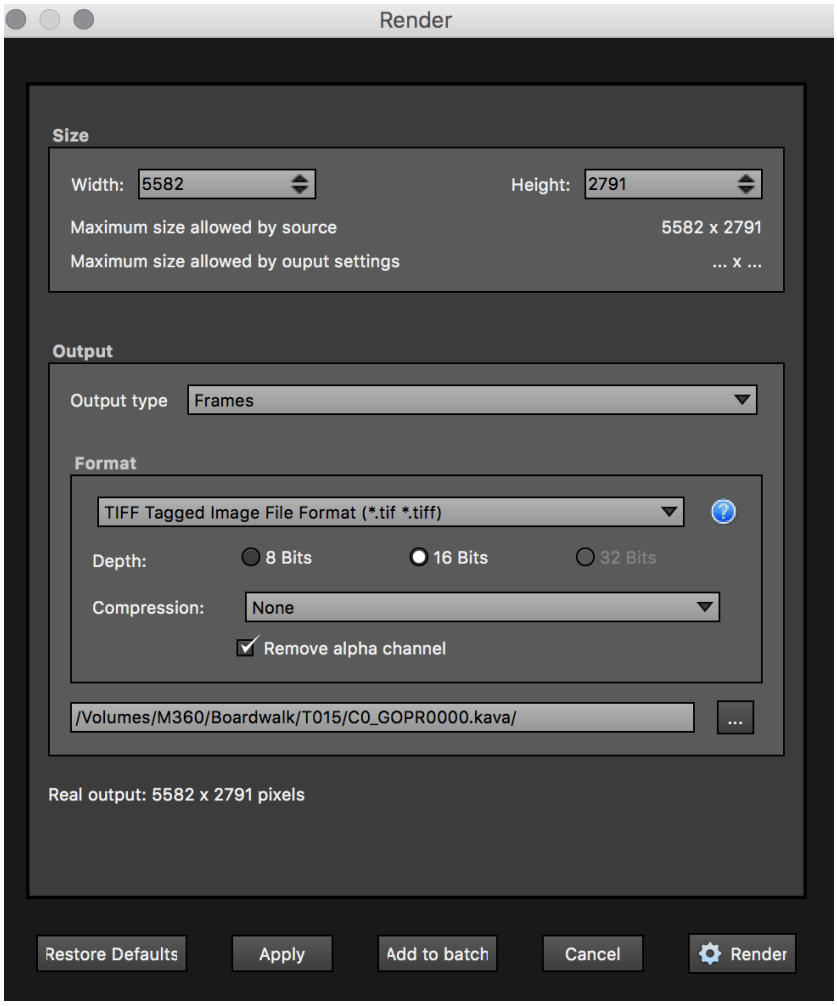
For example, if you want to upload your 360 video to youtube or facebook, the current allowed fps is 24, 25 or 30. For quick stitches, I generally like to set my FPS to be same "as original video" under the Render settings. Setting the default preferences will make it easier to batch render.




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. Remember to change the settings back for your final render. 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).

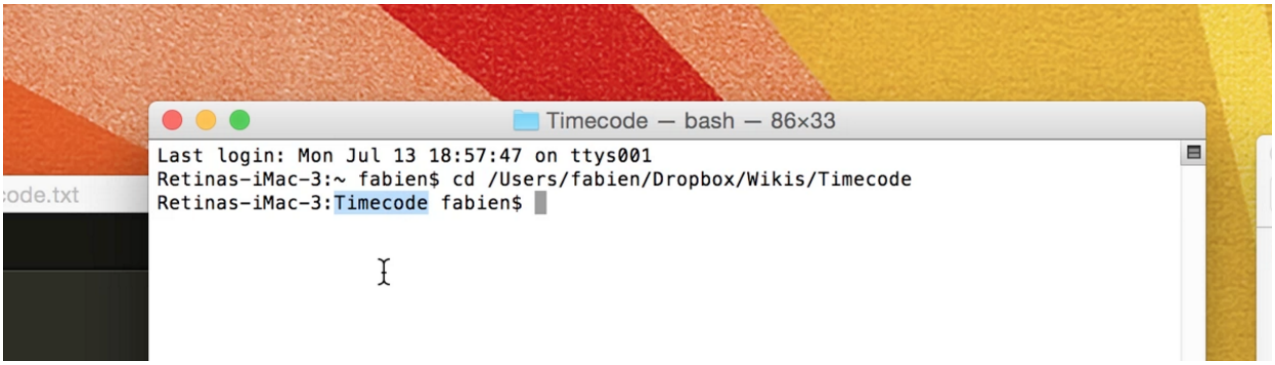
When rendering your fine stitch, it is highly recommended to render output type as frames, a sequence of uncompressed tiff images at 16 bit color depth. You will want to render frames to keep the highest resolution of your panorama and the maximum size allowed. There are limitations when you render videos. 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.

ffmpeg –i video.mp4

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 video_tc.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.

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.

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.

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 was overexposed? Was white balance was 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 and select an individual channel to adjust instead of the main RGB 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  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 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 increasing 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.

# 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. In VR, a dolly shot even the slightest movement of the camera may trigger instant motion sickness and nausea. This occurs

## Solution:

# Patching Nadir

## Problem:

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

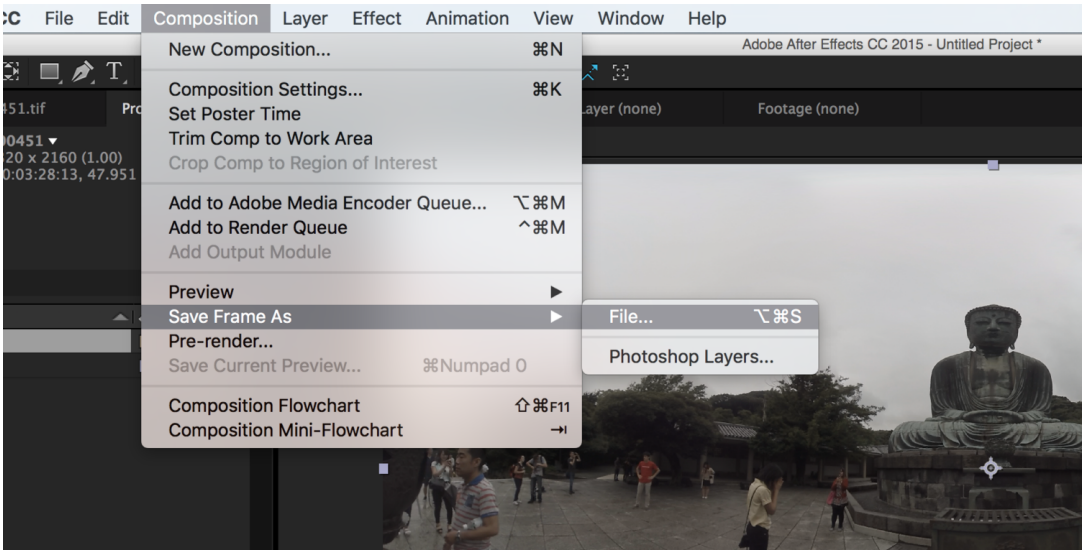
You have stitched your videos but the tripod still shows. You didn't shoot the moon to replace the camera rig and Autopano does not recreate missing pixels. When you try using the red masking markers to hide the rig, some weird blending or a black hole is generated in the panorama.

## 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.

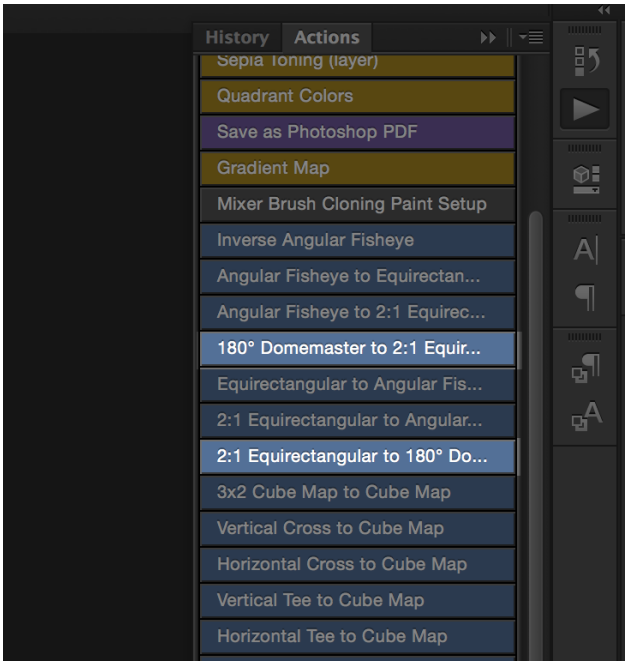
First, install Andrew Hazelden's Domemaster Actions for Photoshop.



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.

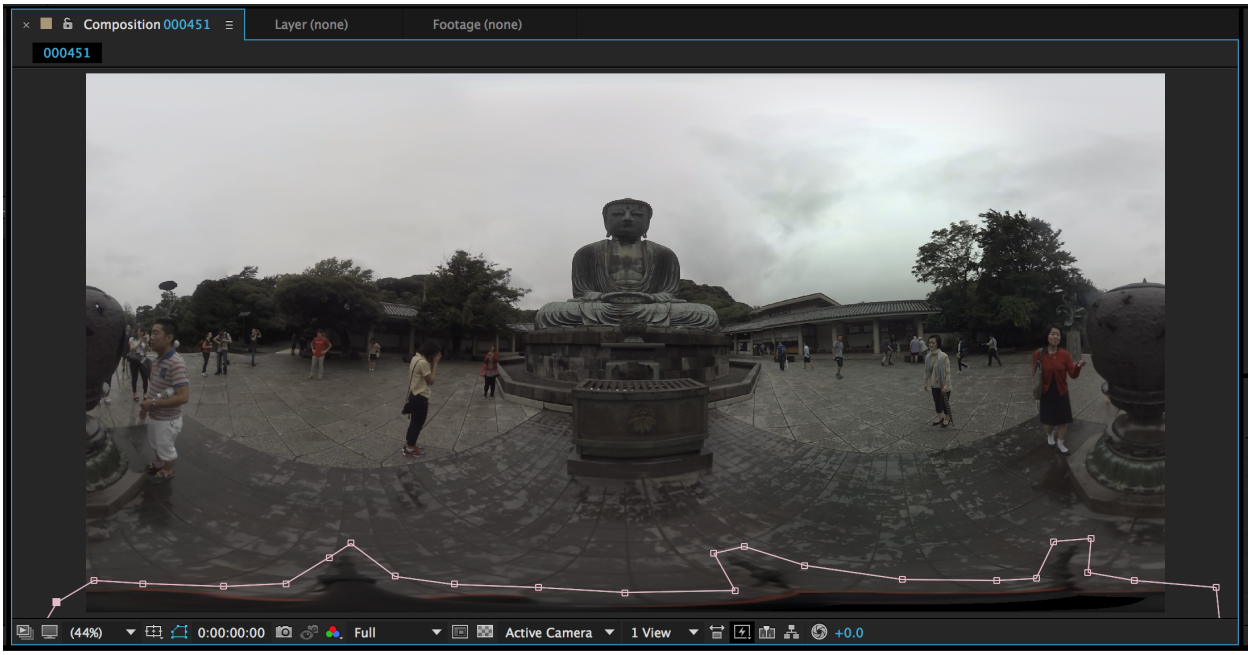



In the Actions list, select 2:1 equirectangular to angular fisheye or 180 domemaster. The panorama format is now converted to a planetarium view. Edit the tripod here using the stamp tool.

**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.

# 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.