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Production of 360° Video

Introduction to 360° video and production guidelines

Helsinki Metropolia University of Applied Sciences

Bachelor of Engineering

Degree Programme in Media Engineering

Bachelor's Thesis

09 September 2016

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Title	Production of 360° Video: Introduction to 360° video and production guidelines
Number of Pages	25 pages + 2 appendices
Date	9 September 2016
Degree	Bachelor of Engineering
Degree Programme	Media Engineering
Specialisation option	Audio Visual Technology
Instructor(s)	Jonna Eriksson (Senior Lecturer)

The main goal of this thesis project is to introduce latest media technology and provide a complete guideline. This project is based on the production of 360° video by using multiple GoPro cameras. This project was the first 360° video project at Helsinki Metropolia University of Applied Sciences.

360° video is a video with a totally different viewing experience and incomparable features on it. 360° x 180° video coverage and active participation from viewers are the best part of this video. This is one of the main key factors of virtual reality. 360° video production technologies, editing software and publishing medias are still progressing their performances.

Keywords	360° video, planning, production method, problems, solutions

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1   Video production planning

Capturing, manipulating and broadcasting moving images is known as a video. A video is a collection of a number of images. Thousands of images need to combine in a proper rate to form a complete and working video. This number of combined images are measured as frames per second which means the number of images combined to create a second of video clip. Quality of video depends upon various factors for example focus, brightness, contrast at shooting, codec applied to code the video, bitrate, spatial resolution and temporal resolution also known as frame rate. A video camera, a computer and a connection between them are the most essential part of video production. Production cost, available features and its different quality differentiate   videos with each other. Price of video, its audiences, and the technology going to be used for production and publishing the video need to be known beforehand. Before we run the camera to capture videos, we should consider following guidelines to get desired video production,

1. Aim of your production

Every work is based on its aim. This applies to all video production as well. The production team should have clear vision about the main aim of particular video production. A proper and clear aim is the main base to start video production process. The aim can be set based on the messages that the video needs to contain or a target audience group or some other factors. This means that there should be one clear aim of the video production beforehand.

2. Audience

All videos may not be suitable for all types of audiences. Groups of audiences can be divided depending upon their age, gender or their interest. Try to figure out the future audiences of your video and plan accordingly. Knowing the audience group helps to study their expectation. According to the audience groups such as kids, young generation and elder people, the video varies a lot. For example, kids like to have funny sounds and the visualisation while young like creative and extraordinary and older people like to have clear sound and clear video to understand the video. Make sure your target people and plan it according to them.

3. Length of your video

Now you have the aim of production and targeted audience group. Based on this you can decide the length of your video. For example, if you want to show some tutorial to children your video should be clear enough. It should contain enough information about it. You may show them a few minute long video but make sure that they will get enough instructions to understand the tutorial. A too short video may lead to many confusions and a video that is too long may not get enough attraction from its viewer. Consider the video material and your audience to figure out the balanced duration of your video.

4. Video quality

Keep in mind all the above-mentioned factors and decide the quality for your video. Video quality depends upon the screen quality, presentation of the video for example startup and ending, titling the video, sound quality and screen size. Getting to know the required video quality provides you the basic idea to choose production cost, camera, video editing software and production duration.

5. Production cost

Production cost limits hardware, software, video quality and the length of the video. Plan a production cost clearly and prepare some extra budgets for emergencies. If your production does not go based on the initial plan, you may run out of money if your budget is too small.

6. Video scripting and storyboard

Scripting provides a subject to the video parts. From a small to big video production there should be some sort of scripting to provide a path to your video. Scripting does not need to be detailed with actions for every single video, it can be a small note with the main subjects or topics. Scripting is the main base to plan the content of your video production.

Correspondingly, storyboard sets the appearance of the scenes in your video. Storyboard is a plan of the scenes that you need to capture for your video. It can be done with a rough sketch or with a list of desired shots.

7. Get to know the event

While shooting an event you need to be known with upcoming scenes. You may not have detailed schedule about the event and there will be a possibility of schedule failure as well. In every formal or informal, familiar or unfamiliar event there should be one timeline, which may not be written or described before. You need to figure out what will happen next and be ready for that so you do not miss it in your preparation. Try to gather as much information as possible but stay ready for exceptions, too.

8. Inspect your location

Decide the shooting location by considering available camera angles, lights, type of event and the scenes. Different locations are suitable for different shootings so keep a note of all the locations and their features that you think might be useful for some shots in future. Some locations are necessary for special shots and some are just beneficial but you need to be known and prepared for all of those possible shooting locations and camera positionings.

9. Available or required equipment and editing software

Keep in mind which camera, tripod, computer and editing software you have to use for your video production. You may even need to prepare for a different set of equipment. At this stage you know the quality, budget, audience, shooting locations and event, so now you can decide the equipment and software that you need to use to reach your goal. [1]

When you have gone through all above-mentioned planning stages you are ready to shoot your video.

2   Introduction to 360° Video

Earth is round in shape but unfortunately we always see a part of it through photos or videos. 360° video is a revolutionary invention to media, because it is capable of showing you every direction of the surrounding. A single video shows you up, down, and all around you in every angle you want to see. 360° video is the only way to see the real world and the events without being in real places, in other words virtually. You can have a complete look of an event that happened in New York city from Helsinki. You do not miss even a small part of the event.

A 360° video is a collection of normal equirectangular videos mapped into a sphere to play. 360° video covers all the inner view of a sphere pointing from centre. 360° videos are videos which have been shot with multiple cameras mounted in a particular rig to capture an entire panoramic view from a particular fixed point. 360° video covers all the footage that appears around the camera except the cameras itself. In simple words the final product of 360° video is a combination of video footages from different cameras mounted in a way to capture different views at the same time. Multiple cameras are applied to capture different scenes with some common footages to each other. All the cameras work together to produce a single 360° video. The number of cameras may vary based on the camera lenses and desired video quality. [16]

Watching any event, a beautiful natural scene and simply whatever you are watching in a rectangle view, is not the real view that you suppose to see. There is a lot (at least ¾ part) that you are not able to see. Everyone thinks at least what is behind the cameraman. What is going to happen next in adventurous events such as race games? There was no answer before, but currently you can just turn your video around with your tiny cursor. You can select your own view angle according to your interest and the importance of the scene. You can continuously change the viewing angle by using your cursor if you are watching it in normal displays as mobile phones or computer. If you are watching VR (Virtual Reality) player by mounting headset in your eyes you need to move your head around.

3 Normal video vs. 360° video

During the 65 years, videos have existed, they have undergone extensive changes. Mechanical television, cathode ray tube (CRT) television and video tape recorder (VTR) are the beginning of videos while 3D, 360° video, 4K & UHD videos are the current video technologies available. Initial videos are not comparable with current ones. Both type of videos have the same purpose which is to show the information to its viewer but the video quality and the way we watch those have totally changed though out the years.

Also today there are many different types of videos available. They are mainly differentiated based on their quality, resolution size and their types. 360° video is the latest video type and it has many changes.

Here I want to conclude a few differences between a normal video and a 360°video. I have categorized the differences based on video contents, its production, publishing and different viewing experiences.

	Normal Video	360° Video
C O N T E N T	1. Normal videos are capable to show only limited areas among the surrounding. 2. Consumes comparatively less storage space. 3. Gets played in many types of video players.	1. 360° video covers 360°x180° spherical area. 2. Consumes a lot more storage space than a normal video. 3. It needs specific type of video players to watch as 360° video.

P R O D U C T I O N	4. One single camera lens is able to produce such videos. 5. Ready to play videos get produced directly from ordinary cameras.	4. For complete spherical view we usually need to use more than 2 camera lenses. 5. Only few specific cameras produce ready videos, in other cases multiple video footages need to stitch separately to make it ready.
P U B L I S H I N G	6. Publishing of normal video with different local video players and online portals are easy 7. Most of the video players support normal videos	6. 360° video needs special attention for example adding metadata confirming the minimum video resolution needed for particular video players while publishing 7. There are not many video players available to play 360° videos with all features
W A T C H I N G	8. Normal videos can be watched with all types of video players just by staring those. 9. Play, Pause, Forward and Rewind are the main options while watching normal videos.	8. 360° video provides a lot of options while watching. 9. In addition to normal videos 360° video provides different angle view option so that the viewer can decide the video angle and watch it actively.

4   Functionality: How 360° video works

As discussed above 360° video covers all inner area of a sphere meaning it covers the 360°x180° angle. Two or more than two separate cameras or a single camera with minimum 2 lenses are able to capture 360° videos. Less cameras is possible only with wide angle lenses. Just like normal videos, 360° video is also a display of moving images. The main idea is that it contains moving images in each direction. Video footages captured simultaneously by different cameras mounted in a purposed circular rig need to be stitched together with perfect time synchronization so that all stitched videos start at the same time.

As we know 360° video is a combination of multiple footages, all the video footages should be captured at the same time and must contain some common footages. Based on those common footages, stitching software inbuilt in cameras or separately generates control points and forms a complete functional 360° video. Proper camera mounting and shooting ensures synchronization at post production and stitching of the multiple videos depends upon common footages to each other of multiple cameras and their synchronization. Video quality and the functionality totally depends upon synchronization and stitching. Based on this information mounting the cameras, starting the camera to shoot video, synchronization and stitching are the main production factors of 360° video.

Stitched video can be published on the internet or viewed locally with proper video players. While playing in the mobile devices all the different video angles can be viewed just by moving or rotating the devices in proper direction. In case of laptops and desktops it allows viewer to drag the video in different direction according to the requirements. This dragging option is also applicable in mobile devices.

5   360° Video Production

360° video production also comes through all the stages of video production planning. In some stages it may need more attention but it cannot skip any of those planning process. It needs more attention mainly at budget, time, hardware and software compared to other video production.

5.1 Camera and their settings

Cameras used to capture the 360° video should be of same model from the same brand, if not their camera settings should be similar to each other. The video footages from different cameras should have the same properties, mainly frame rates, white balance and aspect ratio. In case of less number of cameras (for example 6 cameras) the aspect ratio should be 4:3 to capture maximum area possible. Video footages from all cameras with maximum frame rates allow better synchronization at postproduction. Containing more frames per minute helps stitching software to find same starting point of the videos. Similar white balance decreases the chances to distinguishing different videos after stitching them together.

5.2 Camera mounts

According to the number of cameras, different camera rigs can be used. Camera rig should ensure the mounting of different cameras so that all different video footages contain common spaces to each other in corresponding direction. Depending on those common spaces, stitching software aligns the video footages in proper direction and combines the footages to cover the spherical area smoothly.

Figure 1: Few different camera mounts for 360° video production [2]

As we can see in the picture above there are a lot of different camera positioning possible to capture 360 videos. But the main target of all camera mounts is to capture all spherical area around the cameras with some common footage to each other. All the camera rigs shown above are not able to capture whole 360° * 180° angle but provide 360° video feeling and show a lot more than a single camera or usual videos. The same production procedures need to apply with all different camera mountings and output comes from similar process.

5.3 Video shooting

After setting up the cameras and mounting in proper mounts, video shooting takes place. Starting all the cameras as simultaneously as possible is the key factor of video shooting. Single 360° camera performs this task better than multiple cameras but still it is possible with multiple cameras. 360° video shooting by GoPros can be done with the help of wireless remote. All the cameras can be connected to one remote and operate together easily. With this technique also, different cameras perform in a few millisecond variation. Wireless remote is always recommended with multiple GoPros rather than manual operation.

5.4 Video Synchronization

Video synchronization is the post production of 360° video applied to set the video timing relatively. Synchronization ensures the timing of all videos and helps to make video seamless. Synchronization can be done with a few clicks by stitching software. However, for successful synchronization proper camera settings (for example video resolution, white balance, ISO), appropriate camera mounting so that all footages contains some   common spaces between them and accurate video shooting are very important. Synchronization process is fully based on all these factors. Synchronization failure   directly affects stitching and final output video may be broken or with a lot of seam on it.

5.5 Video stitching

At this stage all different videos get stitched together to form a complete 360° immersive video. Success or failure of this process directly depends upon its synchronization. Successful synchronization leads to perfect, seamless video output. Stitching process provides some control points which can be utilized to improve the stitching.

5.6 Video encoding and publishing

After successful synchronization and stitching the video is ready to encode. Proper video resolution and frames per second based on the targeted video quality are the main factors needed to consider at this point. Before you encode your video make sure where do you want to publish it and apply the recommended settings. YouTube recommends 24, 25, 30, 48, 50, or 60 frames per second and for 4K video quality 3840 X 2160 video resolution and 16:9 aspect ratio. [3]

Till the date YouTube and Facebook are the most popular 360° video publishing tools. YouTube supports wide range of videos with high file size and durations. On the other hand, Facebook has limitations of maximum 1.75 GB in size and less than 30 minutes long. [4]

6   Use cases

360° video can replace normal videos for every purpose. 360° video contains all the features of a normal video and even provides a lot more options. A 360° video is a combination of 2 to many normal videos. Consuming comparatively more storage space, it needs special video players. Also production difficulties are some of the drawbacks of 360° video. Incomparable features surely overcome to these drawbacks. Following are few important use cases of 360° video

1. Live events

Normally live events contain different activities in different areas. Normal videos are only able to show little part out of it in rectangle shape, while 360° video covers all the areas and audience can decide and watch any angle. A single video with total event coverage is an amazing and unforgettable experience. The audience gets an experience of being in the event because they are not missing any scenario. It is mostly   applicable for sports, celebrations, and outdoor or indoor functions.

2. News reports (from incident spot)

As shown in the picture below, 360° video is very useful to do news reporting from incident spot. News are always interesting and contain a lot of information that are more informative to the viewer.

Figure: News video by CNN (A city in morning: Brussels after the attacks) [5]

3. Introducing architectural designs

Historical as well as different designs always interest people. Designs contain a lot of information in every corner. A complete 360° video is able to show a design to millions of viewers in a few minutes. No information misses from there and it is able to save all the information for many years as evidence from history. We have already missed a lot of designs from this world forever. Nepal faced a huge earthquake in April 2015 which destroyed numbers of World Heritage Sites. We may have their photos and videos but those are not enough to prove their importance. Here I have included one picture of 360° video that introduces Snow Hotel which is located in Kemi, Finland. I feel like I am in the hotel when I watch this video.

Figure 3: A tour to Ice Hotel in Kemi Finland [6]

4. Adventure experiences

Many people enjoy sports and also adventure sport activities are enjoyable. When you get a chance to feel like doing it yourself physically feels unbelievable. 360° video is the best media to provide you more entertainment from such sports. Player also can look later how was the entire game was without missing a single second of it.

Figure 4: Screenshots from motorbike riding-360° video [7]

5. Space experiments

Most scientific experiments on spaces are based on photos and normal videos captured by robots or scientists. 360° video not just replaces those but brings great improvements to gather more information from a space. Getting some pictures and videos from space are still great achievements and replacing them by 360° video will send the experiments to the next level.

6. Security

CCTV cameras are the main security measure that has been applied all around the world. Most of the CCTV cameras are unidirectional, and capture only some part. 360° cameras are even better to increase security.

Despite all the benefits of 360° videos, there are some cases where 360° videos are not applicable. For example, TV news from studio, movies and recorded songs. TV studio may be interesting for the very first time but it does not change often; there is a particular area or fixed scene for the audience to see. Movies and videos featuring should not show the production team. The same goes with recording songs. In case of live performances at stage it will be nice to watch the public's reaction from 360° video.

360° video needs extra investment and a lot more efforts to produce so there should be enough interesting scenes to produce it. Above mentioned use cases offers information about maximum surrounding for 360° videos used to their full potential.

7 Problems and their solutions

In video production there are often predictable and unpredictable problems. Here we are going to discuss the predictable problems those may appear during 360° video shooting, stitching and publishing. This discussion will mainly focus on the productions by using multiple cameras. 360° video production with single cameras for example Nokia Ozo, are different than multiple GoPros. Next I will discuss the problems as well as their possible solutions at pre-production, production and post-production stages.

7.1 At pre-production

7.1.1 Collecting equipment

Before starting shooting we need to complete the pre-production successfully. Gathering proper equipment is the main task at this stage. Main technologies that we need to prepare are as follows.

1. Cameras, extra battery and wireless remote

Based on the production plan cameras can have different lenses and differ in quantity. If the cameras contain fisheye lenses, fewer cameras may be enough, otherwise more cameras may need to cover the desired shooting scenes. 6 Go Pros (Hero 4) are able to cover the 360° * 180° angle with proper camera settings. While gathering the cameras you need to make sure all the cameras are of same model or able to provide videos with same quality and properties. Stitching different quality videos produces poor quality with a lot or seams on it.

For proper video shooting by multiple GoPros wireless remote is also an important hardware. Without remote it may not be possible to operate all cameras simultaneously. 360° video needs high resolution video recording which are operated through wireless remote. High resolution video and wireless connection with remote consume quite much battery power, so extra batteries may secure a longer video.

2. Camera rig

Different camera rigs are applicable in different situations. Single cameras that produce a complete 360° video are also available in the market. 360° videos by GoPros have many different choices of camera rigs. Primarily rigs are based on the number of cameras to be mount. Various camera angles may vary depending upon the number of cameras. First confirm the quantity of camera and choose proper camera rig.

Second, distinct rigs are manufactured for live streaming because there need to be wires used to charge or to transfer the videos to video mixture. Rigs made for live streaming allocates places to hide such wires and additional devices carefully.[8]

7.2   At production

As mentioned above all cameras need to be operated simultaneously. Operating through remote control also gives some time differences. Also it is very important to record videos by all cameras. Failure of a single camera may cause distortion of the whole production. Recording small video clips may secure videos. All cameras should record complete videos and therefore always make sure that all cameras are working fine.

7.3   Post-production

Post-production stage may show an error at synchronisation or stitching. In case of synchronisation failure, different synchronization points may be chosen. One may also try for sound and motion detection for synchronization. A few stitching errors can be solved by the help of control points.

8   Future of 360° Video

Since 360° video was launched it has reached an unexpected good level in a very short time. Currently many different events have already been captured as 360° video and a lot of production possibilities have emerged. Production costs are decreasing and production possibilities are increasing. 360° video was a totally new topic for most people around the world but rapid productions in different fields introduced it to wider audiences. Its launch by Facebook helped a lot to make it popular. Most of the football matches, and international events are being captured by many 360° videos.

A few companies have already started to produce their advertisements also with 360° videos. Availability of 360° cameras from around 400€ price is also a huge revolution. News reports with 360° videos mostly by CNN shows its future clearly. 360° video carriers a lot more information than normal news reports. I believe that very soon 360° videos will be produces as normally as other videos and will be very common in big events and international news reporting.

9   360° video camera

360° video is a combination of multiple footages captured by different cameras or a single camera with multiple lenses. It can be captured with all different ordinary cameras by applying settings accordingly but here I would like to introduce a few 360° video cameras which are officially in use for 360° videos and are available in markets.

9.1 Nokia OZO

Nokia OZO is the first virtual reality camera produced by Nokia Technologies. This camera is equipped with 8 camera lenses of 195° field of view to capture entire 360° angle and 8 microphones to record 360x360 surround sound. This is the only complete camera that captures both video and audio in 360° and produce complete video.

A combination of high quality hardware and innovative design Nokia Ozo uses interchangeable digital cartridge to save a complete single file. One cartridge is able to save 45 minutes of video. Ozo can be controlled wirelessly and used with tripod, crane and drone. A complete set of Nokia Ozo costs $60,000.

Figure 5: Nokia Ozo VR camera
[9]

9.2 GoPro Odyssey

GoPro Odyssey is a combination of 16 Hero 4 Black action cameras. This is a complete set of camera rig, cameras and all the necessary hardware and software. GoPro odyssey uploads videos from all 16 cameras to jump assembler to stitch and provides stitched video within 2 days. [15] GoPro cameras can be utilized with separate hardware combinations based on production purpose and budget. There should be minimum 6 cameras to get a complete spherical 360° video.

Figure 6: GoPro Odyssey

Different camera rigs are available for live 360° video streaming and shooting. GoPros are able to produce 4K 360° video with different number of frames per second. GoPro Odyssey costs $15,000 but different configurations may vary the price.
[10]

9.3 Ricoh Theta S

Ricoh Theta S is the cheapest 360° video camera currently available which costs $345. This camera contains two f/2 12MP lenses. This camera is able to capture HD video. It has 8GB internal memory with streaming capabilities. It can be controlled wirelessly by built-in Wi-Fi and view the live video in connected device. [11]

Figure 7: Ricoh Theta S [12]

10 Video stitching and editing Software

Latest 360° cameras come with built-in stitching software. When separate cameras like GoPros are used additional stitching software to combine footages from all cameras to get a complete spherical video is needed.

10.1 Kolor Autopano Software

Alexandre Jenny and Lionel Laissus established Kolor in 2004 to work for SIFT technology. Later on in 2015 Kolor started to work together with GoPro to produce immersive media products. It supplies panorama software, virtual tour software, video-stitching software and hardware for immersive media production. Kolor autopano is a separate software to synchronise and stitch footages from multiple cameras and

edit the videos. Stitched video produced through Kolor autopano can be easily edited with other video editors, for example Adobe Premier, but video properties like video resolution and frame rates should be maintained properly. [13]

10.2 Video Stitch

Video Stitch is another popular stitching software. Video stitch studio stiches offline video footages but VAHANA VR is for live streaming. This is also third-party software to stitch multiple footages. [14]

11 Publication

Publishing 360° is not as simple as a normal video. When we produce one stitched video either directly from camera or after stitching by separate software we should follow some specific steps. Publishing in different platform may need different specifications. Currently most popular publishing web platforms are YouTube and Facebook and virtual reality glasses with other video players.

Adding metadata to the videos is the key step to make it work. When we add metadata to our 360° video, video players play the video in spherical shape and viewer can drag around the video. YouTube and Facebook are the most popular publishing tools currently.

11.1 360° video in YouTube

YouTube is the most popular and widely used tool to publish 360° videos. It is free, easy and accessible for all video producers. Latest versions of web browsers such as Google Chrome, Mozilla Firefox, Safari and Internet Explorer are able to play 360° videos on computers. YouTube applications on mobile devices even offers cardboard view to watch with google cardboard and for many other virtual reality devices.

YouTube has recommended some specifications for frame rates, resolution and aspect ratio. 24, 25, 30, 48, 50, or 60 fps framerate, 16:9 aspect ratio and 4K(3840x2160) resolution are recommended by YouTube. Some cameras add meta data at production. In case not adding 360° metadata to the videos there are instructions how it should be done. [3]

11.2 Facebook

Facebook is also an easy publishing tool for short 360° videos. Facebook has some limitations set for 360° videos which should be considered before publishing a video there. 1.75GB is maximum file size and maximum 30 minutes is the duration of 360° video that Facebook supports. Video resolution is maximum 4K (4096x2048) and not more than 60fps frame rate. 2:1 is the recommended aspect ratio for Facebook publishing for better 360° experience. [4]

12 Own 360° video production

I worked with Lauri Ali-Hokka to experiment our first professional 360° video. As a result we came up with an innovative media production. Among the variety of production choices, we chose 6 GoPro cameras. At the trail stage we used 4 sets of HERO 4 Black and 2 sets of HERO 3 cameras and the trail version of Autopano Pro stitching software. Trial version of stitching software was able to render only 30 seconds of   video. We did not have proper rig to mount the cameras so we used Clay to mount our available cameras. In our first production we failed to get circular stitched video because those cameras were too far from each other and did not shoot required common footage.
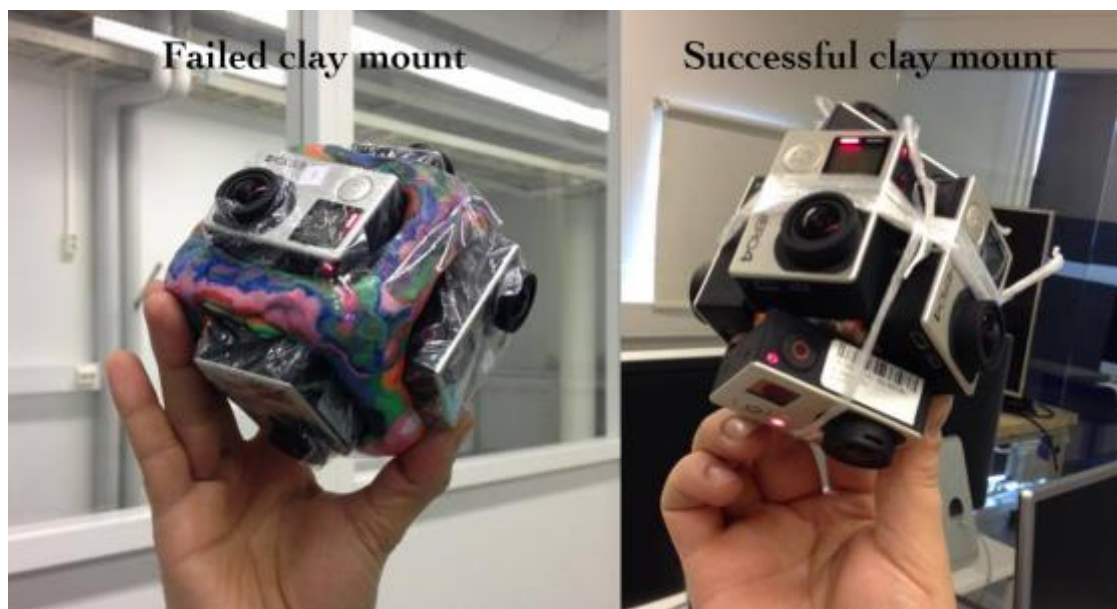

Figure 8: Different clay mounts at trial period

After first failure and figuring out the mistakes we mounted the cameras quite close to one another. Unfortunately, we did not get footage from 1 GoPro because of SD Card error but we tried to stitch the rest of the five video footages. Finally, we succeeded in producing a circular 360° video. This small production taught us requirements for the whole production. After this successful trial production, we went on to produce professional 360° video by organizing all proper technology, which are as follows

Table: Technology used for the production

Technology	Quantity
1. GoPro HERO4 Black 2. Freedom360 mount 3. 64 GB SD card 4. Camera stand 5. Kolor Autopano Video Pro 6. Kolor Autopano Giga 7. GoPro wireless remote 8. Adobe premiere pro	1. 6 pieces 2. 1 piece 3. 6 pieces 4. 1 piece 5. License for 1 Windows PC 6. License for 1 Windows PC 7. 1 Piece 8. 1 Windows PC

12.1   Video production planning

After collecting all required equipment and the computer software we were ready to shoot our first professional 360 video. We had to shoot an event for around 10-15 minutes. We had all the equipment ready with us, shooting place and time as well. Everything was ready and we were looking forward to gain an experience of 360 video production.

Below are the main camera settings that were used for our shooting

Video mode: 2.7K 4:3 aspect ratio

Frame rate: 30 fps

ISO: 800

12.2   Shooting experience

We were at shooting place and we had to shoot a seminar for a workshop. For better synchronization at postproduction, we had to make one sound like a clap or shake the camera for motion detection. We started the shooting outside the seminar room and

clapped to use synchronization with sound detection. Video recording was started by wireless remote control, in which all 6 GoPros were paired beforehand. Shooting was performed with small video clips from 2-10 minus long. Our shooting was of around 35 minutes in total.

12.3 Product analysis

In total our 360° video was 30 minutes and 52 seconds long. It was a combination of different videos. We applied same settings to all cameras which caused some problems in the editing phase and decreased the video quality. Our upper side camera was getting too much light and had same ISO settings which resulted in less details in that footage. This was the main reason for stitching problems and low visual quality.

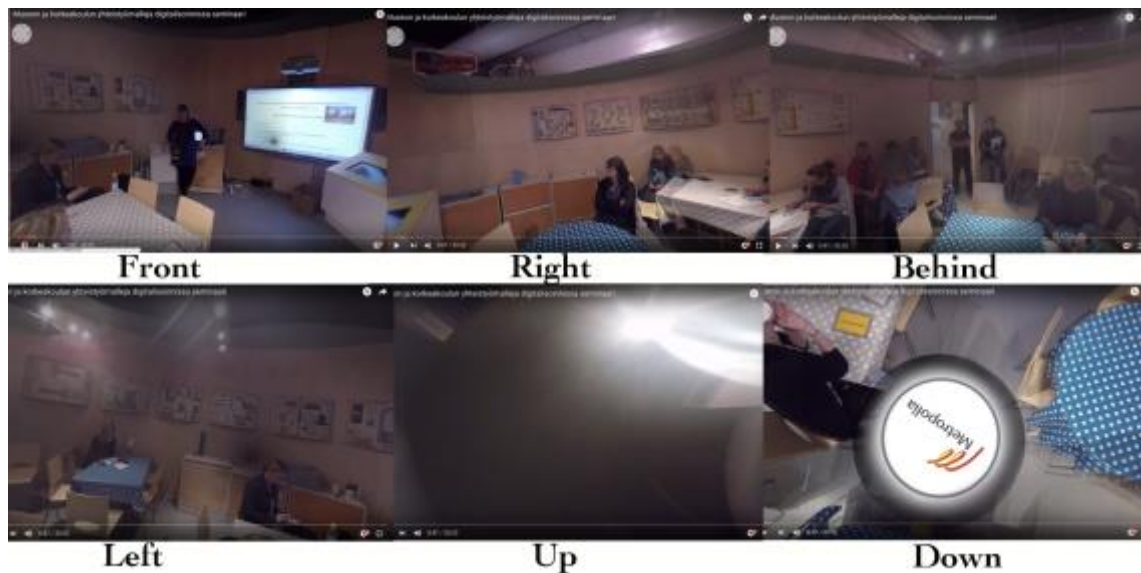Figure 9: Screenshot of final video from YouTube

Figure 10: Screenshots of final video in all directions

As seen in the above image, the upside view is totally ruined by too muvh light, which caused a stitching error as well.

12.4 Problems encountered and their solutions

Learning from mistakes is the best way to learn. Evaluating mistakes and solving the issue brings knowledge that is never forgotten. Here I want to conclude some of my production mistakes and their impact in videos and their solutions, too.

1. Over exposer

When we use multiple cameras to shoot 360° video, we need to make sure that all cameras, will capture quality videos with enough details. After setting same aspect ratio, video resolution and frame rates ISO setting is most important and a tricky setting. Make sure you know how much light each camera gets and balance the ISO accordingly.

While I was shooting my 360° video, multiple times the upper camera was facing direct sunlight or too bright light which caused lack of details from that particular camera. Later on during synchronisation, the software did not find proper synchronisation from that camera and effects to all camera footages. In my case, this was the main reason behind synchronisation and stitching failure. I had the same ISO level 800 for my all 6 GoPros, later I realised that I had to reduce it from upper camera which was facing direct light in the room and sunlight during outdoor video shooting.

2. Black holes

All video compositions were perfect, synchronisation and stitching was good enough but the final published product came with 2 circular black holes at bottom and at top. I spent a lot of time to figure out the reason behind it and finally found the mistake and its solution.

Stitching software requires particular resolutions, for example 3840 × 1920 for putput video, If you want to edit it again with different video editing software such as Adobe premiere for further processing, you should make sure that your final rendering from another video editing software does not exceed previous resolution (in my case 3840 × 1920). Exceeding this resolution stretches the video and leaves such black holes on it.

In my case I used 4K YouTube Pre-set in Media encoder and it was of 3840 × 2160 resolution which was larger than my stitched video resolution.

3. Camera battery failure

Our next problem was the camera batteries. Even though we were using new cameras and batteries they were failing to shoot more than 10 minutes. Operating the cameras by wireless connection and capturing 2K video was the main reason behind it. Longer video shooting should be done by connecting the cameras to direct power source. Another solution is to capture multiple video clips instead of a single long video.

13 Conclusion

360° immersive videos are the latest innovation in the field of video production. There are different than any other videos and carrying a lot information. Virtual reality existed only in theory a few years ago but now 360° video has made it real and accessible to many tech users. 360° x 180° coverage by a single video and making the viewer active is the best part of this technology. Natural and architectural beauty, news reports, live sports and many other programs and adventures sports benefit the most 360° videos.

To cover the entire surrounding around the camera, single camera with multiple lenses or multiple cameras need to operate simultaneously. All the cameras capture separate video footages and get synchronized and stitched at post production to produce a functional 360° video. Stitching program in-built cameras such as Nokia Ozo and Ricoh Theta S output is ready to publish 360° video. But in case of separate cameras without in-built stitching software, additional video stitching software needs to synchronize and stitch all videos together. Adding 360° spherical metadata helps to recognise the video by publishing media.

Currently only a few video players support 360° videos. YouTube and Facebook are the most popular ones. There are some special instructions and limitations officially announced when publishing 360° videos. Facebook limits size and duration of the video while YouTube supports much higher range of videos. One 360° video of length around 5 minutes takes around 5 hours to produce and publishing media on YouTube or Facebook takes almost one hour to finalize after complete upload. 360° videos have pre-production, production and post production difficulties but their features and viewing experience is incomparable.

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Appendix 1: Recommended GoPro settings to produce 360° videos

GoPro image size and framerate

If you are using a **six or a seven camera holder** you must use **only the 4:3 modes** of the GoPro:

- 2,7K 4:3 --> renders a 8K video file
- **1440p (highly recommended)** --> renders a 5.5K video file
- 960p --> renders a 4K video file

Then you have to select the appropriate framerate. As we need to resynchronize the videos in post production you have to use a high framerate, but not to high to keep details in each image. Are the recommended modes:

- **Most versatile mode: 1440p 60fps**
- Static looking for very hi-res output: 2,7k 4:3 30fps
- Want to do slow-motion in post production: 960p 120fps

GoPro settings depending on the workflow

⚠ WIP

Settings	"Quick & dirty workflow"	"Professional workflow with a post-processing in a third party software"
Low light	OFF	OFF
Spot meter	OFF	OFF
Protune	ON	ON
White balance	Set according to the lights of your scene	Native
Color	GoPro (saturated & contrasted)	Flat
ISO Limit	Up to you	Up to you
Sharpness	High	Medium or Low as your convenience
Exposure compensation	See indications below	See indications below

Appendix 2: Facebook recommendations to upload 360° videos on Facebook

Recommended Video Upload Specs

Keep in mind these recommended upload specs:

- We support file sizes up to 1.75GB. Videos must be less than 30 minutes.

- **File type**: MP4 Container

- **Video Codec**: H.264 Video

- **Resolution**: Max 4K input (4096x2048)

- **Dimensions**: 2:1 Display Aspect Ratio

- **Frame Rate**: Up to 60 FPS

- **Pixel Format**: yuv420p

- **Depth**: Monoscopic

- **Projection Format**: Equirectangular

- **Audio**: MP3 or AAC audio, up to 4 channels

Please note, make sure that your video and audio tracks are the same duration in order to avoid encoding errors caused by mismatched timecode.