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Creating high-resolution 360-degree single-line 25K video content for modern conference rooms using film compositing techniques

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Abstract

360-degree image and movie content have been gaining popularity in the last few years all over the media industry. There are two main reasons for this development. On the one hand, it is the immersive character of this media form and, on the other hand, the development of recording and presentation technology has made great progress in terms of resolution and quality.

360-degree panoramas are particularly widespread in VR and AR technology. Despite the high immersive potential, these forms of presentation have the disadvantage that the users are isolated and have no social contact during the presentation. Efforts have therefore been made to project 360-degree content in specially equipped rooms or planetariums to enable a shared experience for the audience. One area of application for 360-degree single-line cylindrical panorama with moving imagery included are modern conference rooms in hotels, which create an immersive environment for their clients to encourage creativity.

The aim of this work is to generate high-resolution 25K 360-degree videos for projection in a conference room. The creation of the panoramas uses the single-line cylinder technique and is based on composition technologies that are used in the film industry. Video sequences are partially composed into a still image panorama in order to enable a high native resolution of the final film. A main part of this work is the comparison of different film, video and DSLR cameras, in which different image parameters are examined with respect to the quality of the images. Finally, the advantages, disadvantages and limitations of the procedure are examined.

1. Project overview

Hotel Park Soltau GmbH developed and built a new type of conference room during the last two years [1]. The conference room "Dortmund" allows 360-degree projection (Fig. 1), which is displayed on the four walls. For this purpose 12 projectors were installed under the ceiling in the room. The control of the presentation is done by a server, in which three graphics cards work synchronously with each other and make it possible to supply 12 HDMI output streams to control the 12 projectors. The whole room can be controlled via a tablet. Scenes, loudspeakers, temperature, illumination, and other parameters can be set from the control tablet.

In this room it is possible to create unique environments. The environments can be computer generated or consist of live action footage with a resolution of 12.000 pix x 768 pix. An important step is the development of a method for the generation of video recordings or moving images of real local artificial environments.

The concept can be used in a wide range of sectors and industries: construction business, architecture, art, entertainment, live events, medical treatment, collaborative working, video conferencing, tourism advertisement, marketing, simulations, and various other applications.

Figure 1. *The Room “Dortmund” at Hotel Park Soltau (Germany) with the projection grid*

2. Basic technological approach

The basic technological idea is to create a still image panorama, and compose videos with moving content in certain parts of the panorama. The advantage of this approach is to obtain a 360-degree environment and this way a perfect guide to include the videos. In rare cases the entire panorama can be filled with video content. Most of the time, relatively little or nothing moves in large parts of the panorama. Also, insignificant movement can be omitted.

The 100K still image panorama of San Francisco taken from the Coit Tower has little significant movement, only boats are moving on the water, clearly visible. Other movements, at various points in the panorama, can be inserted by traditional digital animation techniques, such as the driving of cars in the streets and the movement of cranes on the skyscrapers (see Fig. 2).

Figure 2. *100K panorama with moving objects, San Francisco, CA – recorded from Coit tower*

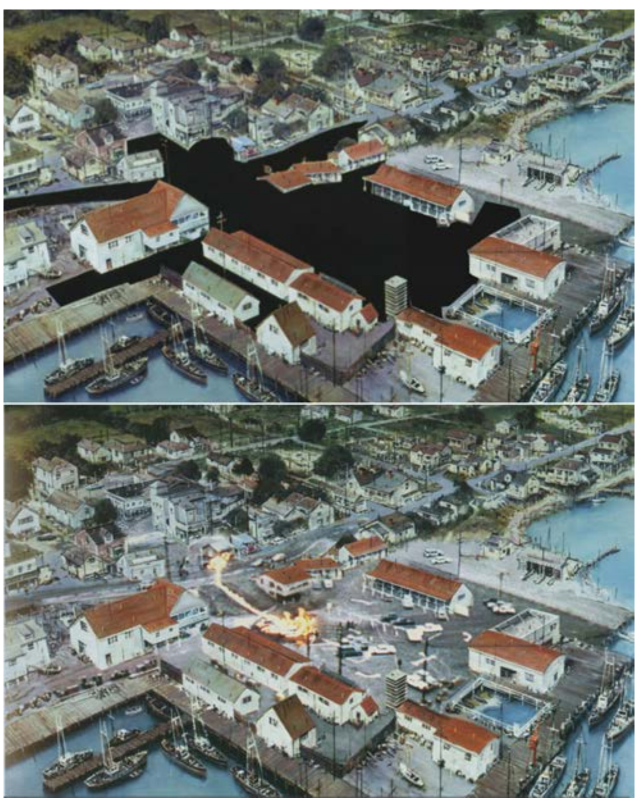

Figure 3. *Matte Painting: The Birds [2]*

The technique described above has been used in movies since the beginning of the last century. Usually, a matte painting was created and masked live action footage was then mounted in. Fig. 3 shows a layout of a famous scene in Alfred Hitchcock's 1963 movie "The Birds". In a long shot the fire of a gas station was shown. The live action footage was then composed into a matte painting of the imaginary city. This film technique requires careful planning, because the matte painting has to match not only the general design but also the perspective.

Fig. 4 shows a panorama recorded in the *Imagination Park* in San Anselmo, CA [3]. Here, only the water feature moves and creates small waves in the separated area of the water basin.

Figure 4. *Partial movement of water feature in large panoramic still image in Imagination Park San Anselmo, CA*

On the other hand, in Fig. 5 the whole heather is moving in the foreground, because a strong wind was blowing at the time of the recording. The video coverage in the left part of the panoramic image is larger because also the trees in the background are moving. The overlapping areas are needed to create a seamless movement, whereas the lowest part of the panorama does not appear in the final image.

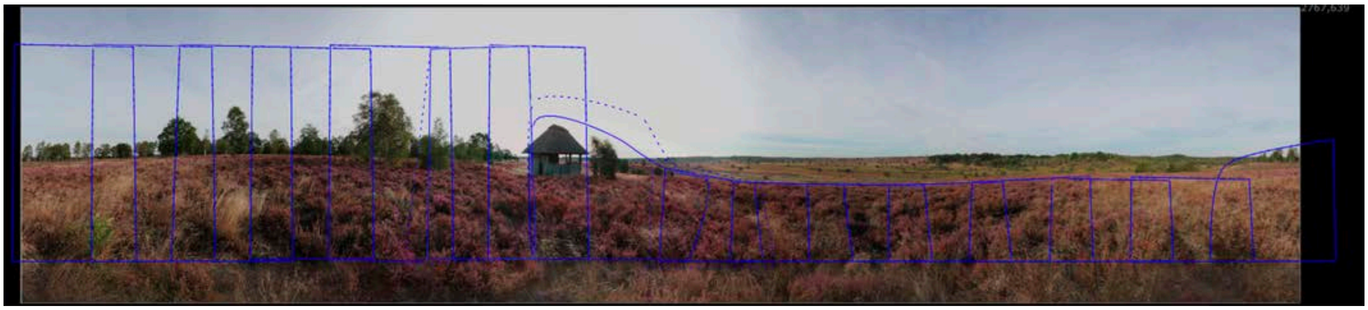

Figure 5. *Panoramic image with large areas of video content (Lüneburger Heide, Germany)*

When still images are used as a basis, it is easy to make retouches and other changes, as these areas do not change in the video sequence. Fig. 6 shows a group of hikers in the image. They can easily be painted out.

Figure 6. *Easy removal of moving objects in large panoramic still image*

During the recording process of the 360-degrees panoramic footage it is necessary to avoid that elements are crossing the recording areas, because the scenes are recorded at different times. It is helpful to optimize the overlapping of the individual video recordings depending of the speed, size and direction of the moving elements in the scene (Fig. 7). When playing footage in a loop it is recommended to avoid directional movement of video elements.

Figure 7. *Moving objects are crossing recording area*

When recording an area with large directional movement, like a highway with moving cars, or ocean waves, it is often difficult to blend the movement of the elements from one video part to the other. Here, foreground elements can serve as natural boarders to limit and hide movement like in the example of the movie “Iron Man 2” [4]. There, the images are blended together by inserting a computer graphics bridge at the border of the video parts where the cars can hide (Fig. 8). For the panoramic image of the Lone Cypress in Monterey (CA) the trunks of the trees can be used as borders to hide ocean water movement when blending the different video footage (Fig. 9).

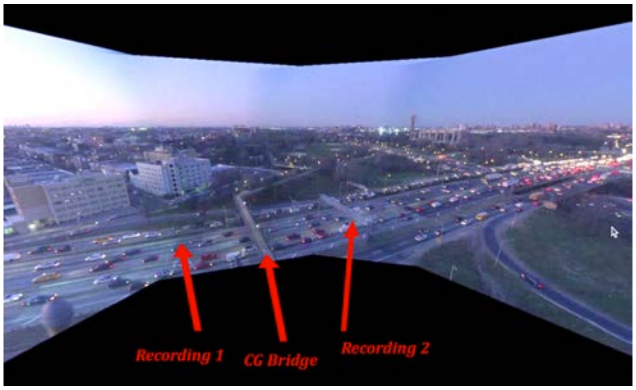

Figure 8. *Production plate of the movie "Iron man" with a computer graphics bridge to hide car movement [4]*

Figure 9. *Tree trunks and rocks (red) as boarders to limit water movement between different video footage*

3. Recording equipment for the 25K panoramic video production and projection

3.1. Video production equipment

Initial tests were performed with panoramic videos with a horizontal resolution of 8K. They showed that the resolution, was too low to meet the quality requirements for a 360-degree projection.

In further tests, it could be determined that the 360-degree videos produced with the 25K method described here, which was developed at the Technische Hochschule Brandenburg in 2011, basically meet these quality parameters. This method was presented in 2012 at the Campus Party Europa in Berlin Tempelhof, Germany [5]. However, it was determined that the video quality of the Canon EOS 5D Mark III camera used was not sufficient since the video is blurry (Fig. 10).

When selecting the recording equipment, care was taken to ensure that it consists of stable and robust components that are easy to transport and flexible in use. The selected leveling plate allows fast and accurate alignment of the rotation plane. The single-line panorama head offered the ability to use snap-in angle intervals, which speed up the recordings considerably.

Figure 10. *Comparison of the still image area in the panorama (bottom) and the poor quality video (top)*

Figure 11. *Equipment used for 360-degree single-line panoramas*

The used camera Canon EOS 5D Mark IV offered sufficient video quality due to the higher video resolution (4K) and the improved optical low pass filter. Also, the color subsampling was improved (4:2:2), and the Motion JPEG video codec provided a better quality than the standard H.264 codec delivered by the camera.

List of used recording equipment (Fig.11)

1. Tripod – Novoflex QLEG C 3940
2. Leveling plate – Novoflex MBAL-PRO75
3. Panorama head – Novoflex VR SYSTEM III
4. Camera – Canon EOS 5D Mark IV
5. Lens – Canon 16-35 f/4 L IS USM, focal length images: 24 mm, video: 16 mm

3.2. Video projection equipment

The projection system covers a room with dimensions of 30.68 ft x 26.25 ft x 8.23 ft. The arrangement of the 12 projectors and part of the projected image are shown in Fig. 12 and 13.

Further parameters of the video playback are:

- Picture width: 12000 pix
- Picture height: 768 pix
- Video Codec: DXV3
- Data rate: 617168 kBit/s
- Total bit rate: 618703 kBit/s (difference is audio)
- Frame rate: 25.00 frames/second
- Projection Software: Resolume Alley 2.0.2 [6]

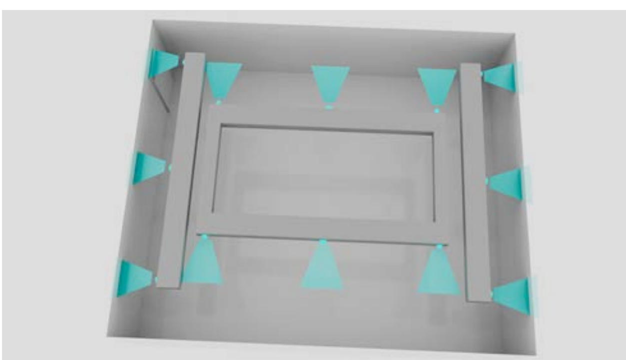

Figure 12. *Setup of 12 video projectors in 360-degrees projection room*

The used resolution of 12000 x 768 pix is strongly influenced by the Nvidia mosaic, which combines the projectors on the hardware level to one monitor. However, as this has a maximum resolution of 16384 pixel horizontally or vertically, the entire resolution of all projectors is downscaled to match this value:

$1920x12 = 23040/16384 \approx 1.4$

$1080/1.4 \approx 768.$

Thus the resolution of the video height of 768 pix results from the conditions of the graphics card.

However, the width is further reduced by the projector overlapping, which is not included in the NVIDIA mosaic calculation. Thus only a width of 12 000 pix is available.

Figure 13. *View into the conference room "Dortmund" in Hotel Park Soltau with 360-degreen Hi-res video projection [1]*

4. Overview of the workflow

TV and video production are currently characterized by massive developments in display and projection technology. Especially developments in the High-dynamic area are changing the way visual content is viewed. But the size parameters of videos are also subject to these changes.

In the document Recommendation ITU-R BT.2123-0 (01/2019, which describes video parameter values for advanced immersive audio-visual systems, a horizontal resolution of 360-degree (30K) panoramic imagery is specified.

> *These values are based on typical human spatial angular acuity for viewers not to perceive a pixel structure when viewing part of a 360° image. A pixel count of 30K × 15K is required for a full 360° image [7].*

Due to the camera and focal length used, a horizontal resolution of approx. 25K is achieved with the method presented here. To obtain this, 16 Raw images are taken upright with the Canon EOS D5 Mark IV camera in CR2 Raw format and assembled into a panorama in PTGUI Pro 11.19 [8] (Fig. 14). According to the developer [9], the raw data is exported in sRGB color space. To keep the amount of data small, JPEG is chosen as the file format. Since the video footage uses a codec that is also based on JPEG, the final quality was considered sufficient.

Since the resolution of still images is 4480 x 6720 pix, the panorama image has a height of about 4.5K at this point in the workflow. The 25K x 4.5K panorama image is then imported into *The Foundry Nuke* [10], and the video footage is attached.

The vertically recorded videos have a resolution of only 2160 x 4096 pix. In contrast to the predecessor model Canon EOS D5 Mark III, only the area of the sensor that has the above-mentioned number of photo elements is used for the recording. This results in an equal number of photo elements and pixels. However, this changes the equivalent focal length and thus, the crop factor to 1.64. In order to achieve a more or less equal image section, a focal length of 16 mm was chosen for the video recordings.

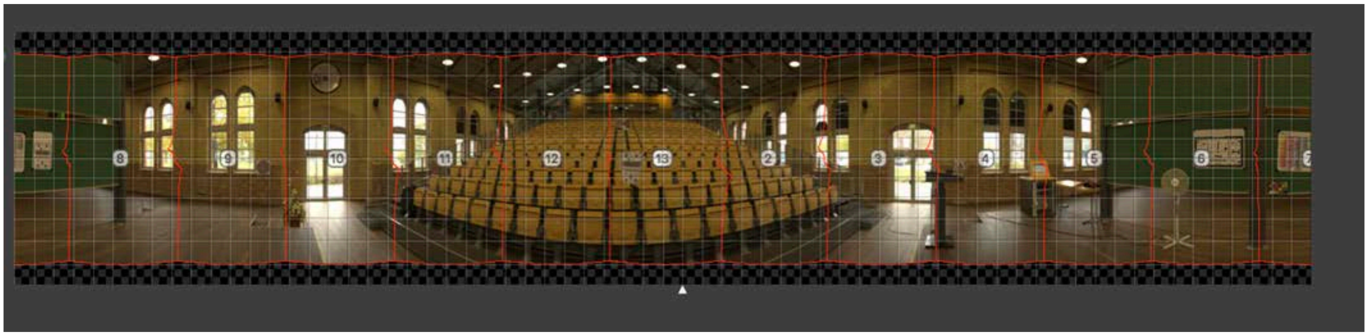

Figure 14. PTGUI Pro stitching areas of individual images

Since the image size still did not correspond to the height of the still panorama, the video was enlarged by a factor of about 1.3. After placing and scaling the videos over the still panorama, the color correction was done. Masking and other composition techniques were also applied to ensure a seamless transition between image and video areas.

Afterward, the video was scaled horizontally to 12000 pix, because only a count of 768 lines was available vertically. For this purpose, several aesthetic viewpoints had to be considered, such as:

- Distribution of the videos mostly in the straight wall areas,
- Placing dominating elements in the corners,
- Avoiding setting the horizon too low, so the sky does not occupy too much space,
- Avoiding setting the horizon too high, so the content of the picture may not appear too dominant,
- Adjusting the panoramic floor to the videos content to avoid a further transition from the video area to the still image,
- Covering most of the panorama area with the content of the still image (Fig. 15).

Figure 15. Maintaining overall quality by reducing the video area

As an aid to decision-making, the room was roughly modeled as 3D geometry, and the video to be projected was applied as a texture in the Nuke 3-D space.

Finally, the video was rendered as a Targa image sequence as master, from which a color-corrected Quicktime video with the DXV3 codec was generated as the final product.

5. Digital compositing techniques

Compositing is a central technique of moving film production. Almost no blockbuster nowadays can do without visual effects, the final processing step of which is compositing. Here, all the assets created in the pipeline are combined into a coherent overall picture in such a way that the viewer can no longer tell which individual parts make up a picture. Compositing knows many areas, tools, and procedures, whereby three applications should be highlighted here as examples [11].

5.1 Using masks – rotoscoping

Masks are used to combine two images, usually a foreground object with a background from another source. Rotoscope masks are created manually. Modern moving image production provides many examples of their use. Particular image areas can be extracted or left out by applying a mask. They can be highlighted or processed with further image influencing methods such as filters. In compositing, the primary technology is rotoscoping, since vector data is used here that does not generate any edge noise in moving images, as would be the case, for example, if a digital brush was used. [12].

In Fig. 16, the branches leave the recording area due to the strong movement and are thus cut off. To prevent the cut-off, the branches in the video were removed at the edge of the video applying a rotoscope mask. In the still panorama, a gradient was added as background, over which the corresponding branches in the still image and in the video were placed.

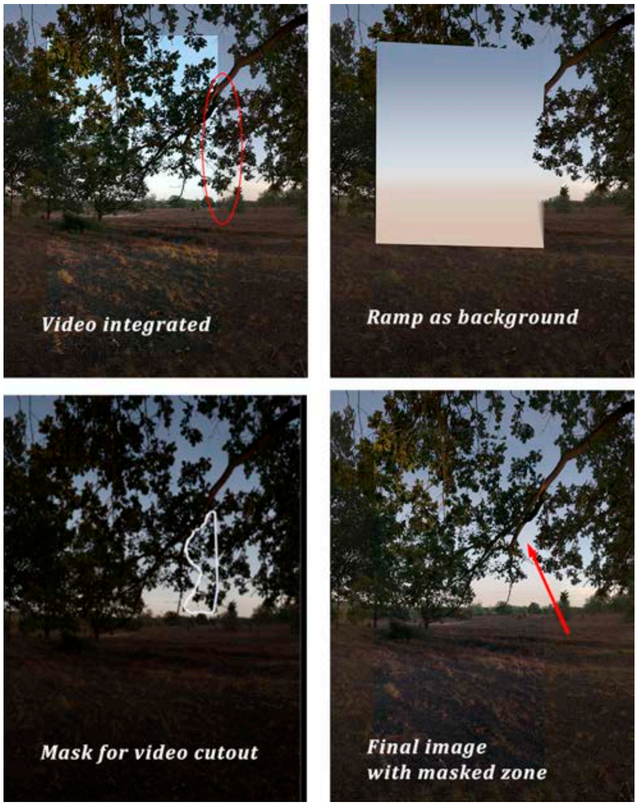

Figure 16. *Rotoscoping used in panoramic image*

5.2 Tracking

Tracking is an essential part of modern postproduction in film and TV. The algorithm tracks visual patterns and delivers the path of the moving object. Other elements such as text, images, 3D objects are tied to the path and follow the original movement of those patterns in the live-action footage [13]. In Fig. 17, tracking is used to stabilize the handheld video recording.

Figure 17. *Tracking used to integrate handheld video in panoramic image*

5.3 Vector-based clone painting

Clone painting in compositing is the idea of copying parts of an image or video from one position to another. The aim is to replace the content or to expand the imagery. For the copying process, a source area is defined, which is connected to the target area by a vector. Since this relationship is constant, the copied material does not change or flicker, and this way noise is avoided [11]. In Fig. 18, areas of the heather with no recordings were replaced by copying other footage.

Figure 18. *Seam removal by clone painting from adjacent videos*

6. Comparison of different recording devices

In the following test, we were examining to what extent other cameras are capable of creating a corresponding 360-degree panorama. By comparing the results, new insights were to be gained, which are aimed at improving the quality of the images or simplifying the handling. The test cameras are a selection of different cameras that have a moving image recording function (film camera, video camera, DSLR cameras, smartphone, consumer photo camera with video function). The test was carried out in the Audimax of the Technische Hochschule Brandenburg, Germany.

All these cameras create a single-line 360-degree panorama. For this purpose, 16 still images (or if not possible, a short video sequence) were recorded. Likewise, a video of a rotating fan was recorded and integrated into the still panorama. Afterward, the color correction was made for the panoramas of the different cameras. Finally, the results are compared according to the following categories:

- Ease of use
- Still image panorama sharpness
- Video sharpness

The following cameras were used in the test. If possible, the same lens was applied.

- BlackMagic URSA Mini Pro 4.6K
- Canon EOS 5D Mark II
- Canon EOS 5D Mark III
- Canon EOS 5D Mark IV
- iPhone 7 Plus
- Panasonic LUMIX GX80 (+ VILTROX EF-M2II Adapter)
- RED SCARLET MYSTERIUM-X
- Canon 16-35 f/4 L IS USM lens

The resulting panoramas of the test are depicted in Annex A.

6.1. Color transform and used file types

To be able to compare the panoramas of the individual cameras, a color correction had to be carried out. The problem is that film, and video workflows differ considerably:

- Display-referred vs. scene-referred
- Linear vs. perceptive uniform
- HDR vs. SDR
- Wide gamut color space vs. standard gamut color space
- Dark vs. dim (TV) or bright (consumer) viewing environment

The film workflow (ACES) was chosen in order to test the quality of the recordings of the film cameras.

The video sequences of the URSA Mini Pro 4.6K were converted to the ACEScg color space in Blackmagic Resolve15 with the settings according to Fig. 19 and exported as OpenEXR files. These files were then assembled in PTGUIPro11.19 and exported in ACEScg color space as well. The still image panorama was then imported into Nuke as an ACEScg encoded file. An OpenEXR sequence was created for the video using the same workflow.

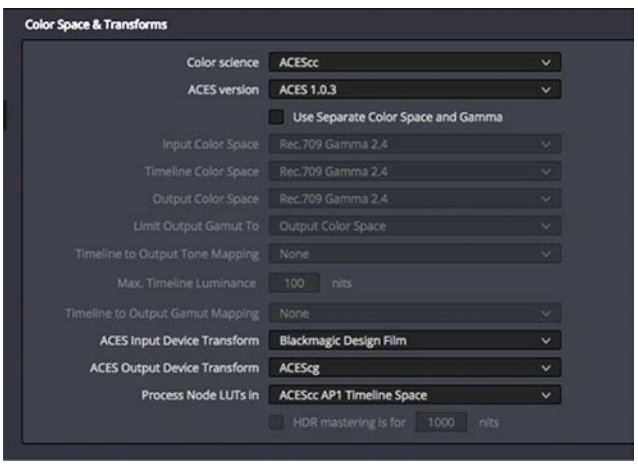

Figure 19. *Blackmagic Resolve Settings for exporting Blackmagic Ursa Mini Pro 4.6K footage to ACEScg*

The 16 CR2 panorama images of the Canon D5 cameras were imported directly into PTGUI Pro. The panorama was output in *sRGB* color space by default and imported into Nuke using the OCIO ACES1.1 configuration: *Basic – Input – Texture – sRGB*. The corresponding Quicktime videos with the Motion-JPEG codec were imported with a custom made OCIO transform *Input – Rec.709* [14]. Using the OCIO *Utility – Camera – Rec.709* transform would show the same results.

The iPhone JPEG images, encoded in *sRGB*, were directly loaded into PTGUI Pro. The exported panorama was then imported into Nuke using the OCIO transform *Basic – Input – Texture – sRGB*. For the video input again, the custom made OCIO transform *Input – Rec.709* was used.

For the Panasonic LUMIX GX80, the same workflow was used as for the Canon cameras, with the difference that these were RW2 Raw files.

The RED camera offered the possibility to create still images. These were imported into Nuke by converting from the *REDLog3G10 – REDWideGamutRGB* color space to *ACEScg*. The output was as OpenEXR files. These images were then stitched into a panorama in PTGUI Pro and imported into Nuke as *ACEScg*. For the videos, an OpenEXR sequence was created with the same workflow.

To compare the results, the color correction was done in Nuke. As usual in the film industry a linear value of 0.18 as a reference was chosen. This was achieved by using the Macbeth color chart, and here: Patch #22 of the color chart neutral 5 (.70D) with 0.1915 linear [15].

Table 1 shows the settings in the Nuke Grade node to achieve this result. It is visible that the color values for patch #22 are too low for all panoramas. With the given settings, for all cameras except the iPhone, the peak white is shifted into the High Dynamic Range (superwhite). It is also noticeable that due to the predominance of artificial light (incandescent lamp) over daylight, the blue channel has to be increased considerably.

	R	G	B
URSA mini pro	1.6890	1.9268	4.6086
Canon D5 Mark II	2.9123	3.5877	8.2500
Canon D5 Mark III	2.6409	3.1817	7.4856
Canon D5 Mark IV	3.0398	3.6654	7.7072
iPhone 7 Plus	0.6878	0.7131	0.9765
LUMIX GX80	2.9451	3.6147	7.3639
RED Scarlet-X	3.8067	4.0915	9.1601

Table 1. *Nuke Grade Node Settings*

Looking at the values of the reference region (Fig. 20) with the peak white in the panoramas (Tab. 2), the color values of the videos show a value of about 3, whereby the images of the film cameras were considerably increased. The ACES system used here with its Output Transform (RRT+ODT) compresses (rolls-in) only values up to 16.3 back to 1.0 (Tab. 3). The values above this are truncated. This concerns especially the RED camera. Thus, detail close to the peak white is lost. The ACES output transform compresses the values of the videos above 1.0 as well, so the already high contrast in the videos is increased further.

	R	G	B
URSA mini pro	10.33167	10.32425	10.34852
Canon D5 Mark II	2.81073	3.45800	7.99679
Canon D5 Mark III	2.53846	3.06595	7.28917
Canon D5 Mark IV	2.92904	3.53421	7.47357
iPhone 7 Plus	0.65090	0.67415	0.92082
LUMIX GX80	2.85666	3.48987	7.13952
RED Scarlet-X	20.53004	21.81951	49.64100

Table 2. *Peak Values after correction in peak white area*

A special case is the iPhone. To get the same values for Patch #22 as for the other panoramas, they had to be reduced. As a result, the peak white was displayed in grey. The iPhone panorama was then color corrected to a value of 1.0 in the peak white region.

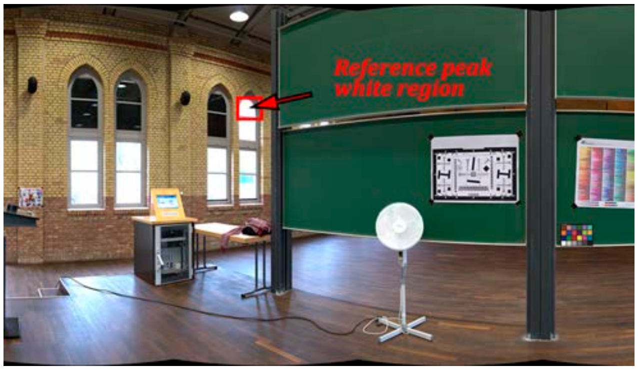

Figure 20. *Peak white reference region in the panoramic imagery*

	R	G	B
URSA mini pro	0.99891	0.99999	1.0000
Canon D5 Mark II	1.00000	1.0000	1.0000
Canon D5 Mark III	1.00000	1.0000	1.0000
Canon D5 Mark IV	1.00000	1.0000	1.0000
iPhone 7 Plus	0.78333	0.82150	0.97947
LUMIX GX80	1.00000	1.0000	1.0000
RED Scarlet-X	1.00000	1.0000	1.0000
iPhone 7 Plus corr.	1.00000	1.0000	1.0000

Table 3. *Peak white values after ACES Output Transform*

6.2 Ease of use

Light and robust equipment is the fundamental prerequisite for the flexible production of panoramas, as often the shooting location cannot be reached by transport vehicles. The selected equipment has proven to be extremely reliable, as many of the test shots were made in the nature reserve Lüneburger Heide, Germany, where motor vehicles are not allowed, and the equipment had to be carried.

Figure 21*. Placement of DSLR camera (left) and movie camera (right) on panorama head*

Figure 22. *Quality of video, integrated in panoramic image – movie cameras*

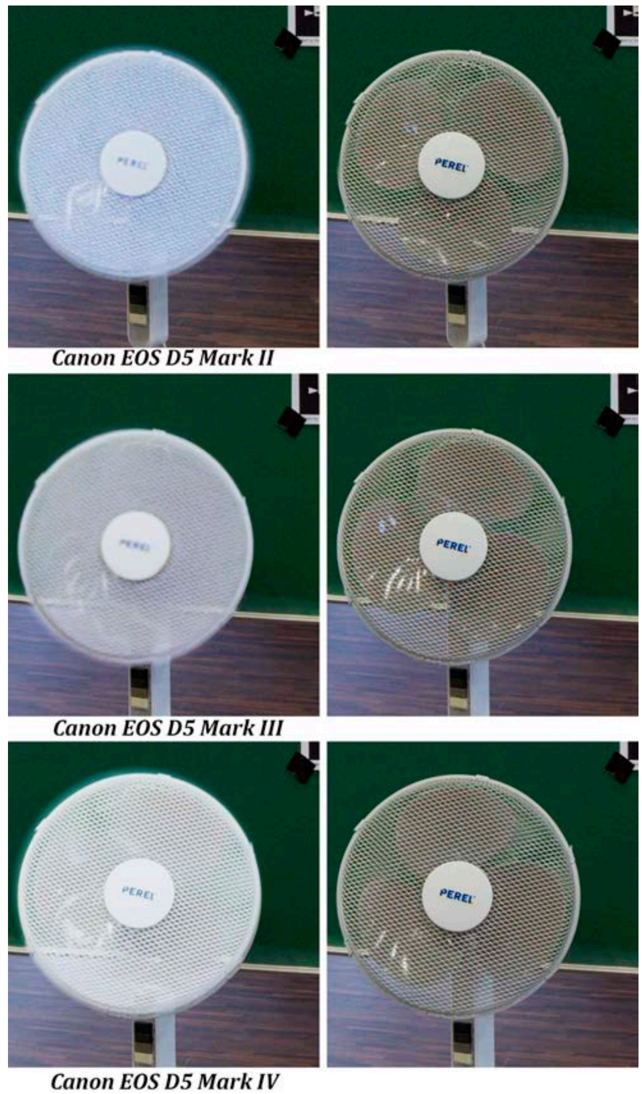

Figure 23. *Quality of video, integrated in panoramic image – Canon DSLR cameras (video left, image right)*

The cameras used in the test could be attached to the panorama head without any problems. However, the film cameras (Blackmagic, RED) in the test were too large to adjust the nodal point correctly (Fig. 21). For a professional recording, it would, therefore, be necessary to install further adapters to adjust the nodal point in such a way that a parallax shift is excluded. However, this would further complicate the recording technology.

6.3 Video sharpness

In this partial test, it was examined to what extent the film cameras can improve the quality of the videos inserted into the panorama. To achieve the same movement, a large fan was started and stopped. This made it possible to capture the movement of the rotors as they moved out. As a basis for discussion, the still image and a video image are shown for all cameras in the test.

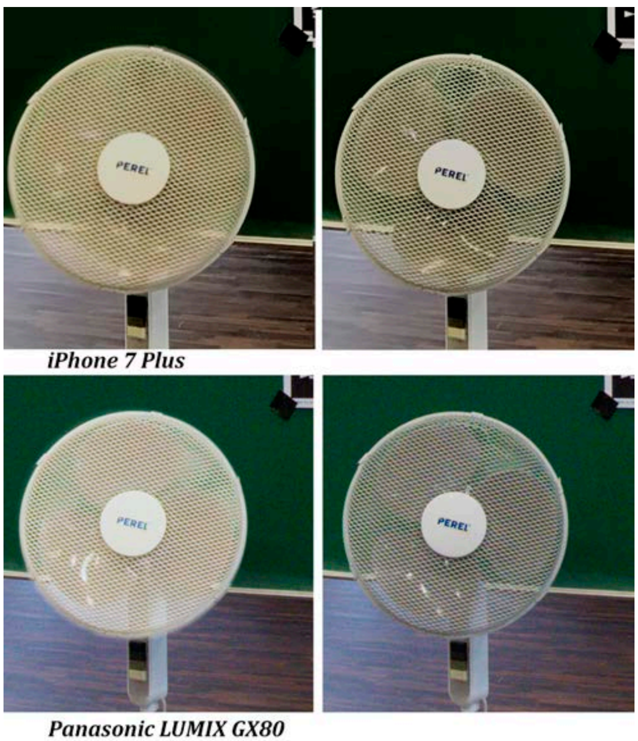

Figure 24. *Quality of video, integrated in panoramic image – Photo cameras (video left, image right)*

For film cameras, the still image and the video are the same, since the still images were generated from the film footage, which in the case of the RED camera consisted of only one frame. Both film cameras (Blackmagic URSA mini-Pro and RED Scarlet-X) provide good, hardly distinguishable results. With the Canon D5 cameras, a quality development is visible. Mark IV delivers the best results. The Panasonic Lumix has a little more detail. The very bright burned out areas of the Mark IV video are mainly caused by the strong compression of the applied ACES Output Transform. An adapted video workflow could deliver better results here. Interestingly, at first glance, the results of the iPhone are also quite acceptable.

6.4. Still image sharpness

In this partial test, the quality of the still images is examined. This quality parameter is very important since most of the panorama is composed of still images. A Siemens star test image [16] was used, which was placed about 10.75 ft from the shooting position.

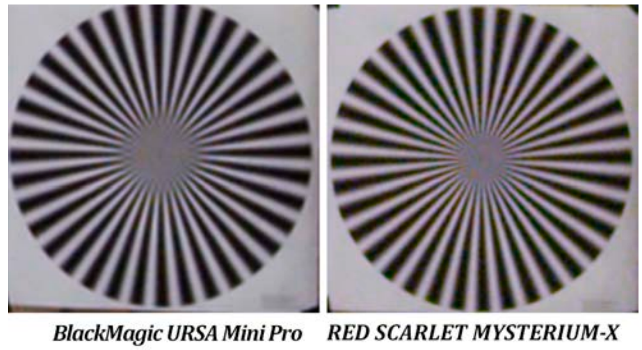

Figure 25. *Quality of still images – movie cameras*

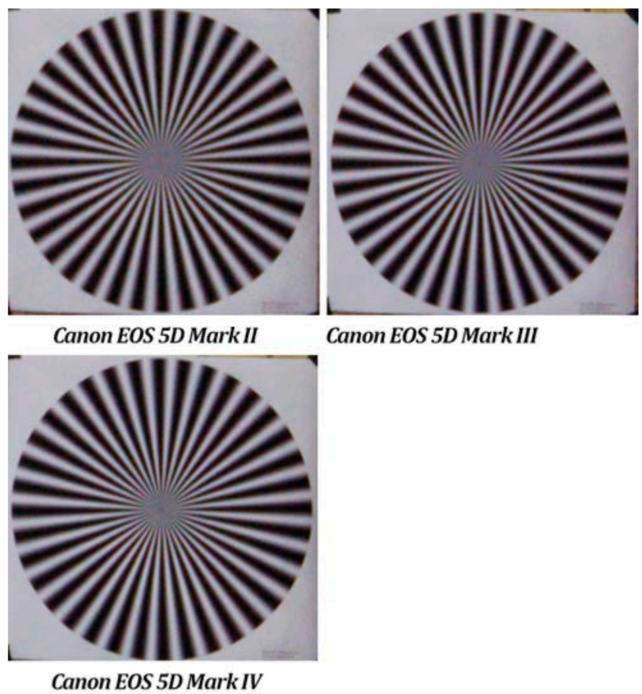

Figure 26. *Quality of still images – Canon DSLR cameras*

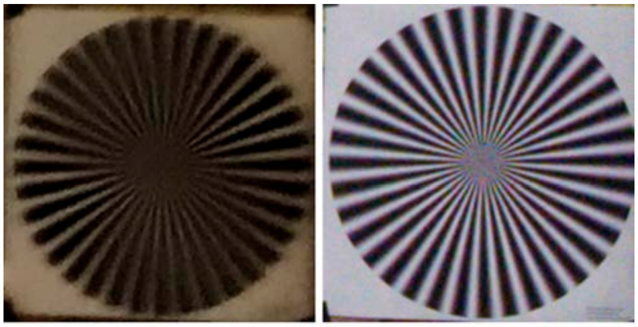

***Figure 27.** Quality of still images – photo cameras*

When comparing the Siemens star, which was recorded with the cameras used in the test, the camera has the best quality, which retained the center detail the closest. Among the film cameras, the RED camera is a little better. The diameter of the grey circle is smaller than the URSA mini. This grey circle results when the camera reaches the limit of resolution. With Canon cameras, the quality improvement is visible, but not as strong as with videos. The Canon Mark IV camera gives the best results. It not only comes closest to the center, but also suppresses the Moiré pattern [17] best. The iPhone visibly reaches the limit of resolution, which is mainly caused by strong noise reduction.

8. Conclusion

The creation of a high-resolution 360° panorama is a complex and challenging task, as the quality standards for the projection room (> 12k) must be maintained. This paper offers solutions for the following problem points, which are important in practice:

1. vibration-free leveled plane of rotation,
2. exact nodal point panning to avoid parallax shift,
3. constant rotation intervals with sufficient overlapping,
4. maintaining constant exposure settings,
5. dealing with high dynamic range lighting situations (sun reflections),
6. establishing a professional color management workflow,
7. stitching the images distortion free,
8. carefully planning of video shooting,
9. integrating footage into panoramic still image,
10. video color workflow,
11. video compositing,
12. selection of projected image area,
13. adjusting panorama to projection room geometry.

The approach described in this paper has been proven by practical examples. The application scenarios were implemented in the Hotel Park Soltau in the projection room "Dortmund." The extensive tests have shown that the presented method is beneficial and delivers excellent and future-proof results.

Nevertheless, there are situations in which it is difficult to take a panorama.

1. Many different local movements e.g., people on the beach: Here, non-essential elements can be painted out.
2. Strong directional movement – no loop possible: It can be limited by natural boundaries like trees, objects, rocks.
3. Continuous movement in large parts of the panorama, like an ocean: it can be smoothed in postproduction with clever masking techniques.
4. Strong reflections of the low sun in the water: Especially, the videos have to be adjusted in postproduction with masking techniques and color grading. It is recommended to record the videos with different exposure settings.
5. Small rooms: Here the vertical representation of the conditions of the room to be recorded is determined exclusively by the geometry of the projection room. Due to the ratio of projection length and projection height, only a section of the room can be displayed, which is usually unsatisfactory. This is due to environmental reasons and cannot be changed.

Further investigations and improvements to the workflow will include the following topics:

1. Color workflow: Here, it is to be examined to what extent the conversion of the raw image data with the *rawtoaces* converter directly into the ACEScg color space achieves better results than using the conversion in PTGUI Pro.
2. HDR recordings: Here it is to be examined to what extent the better HDR possibilities of film cameras can represent strong reflections of the sun in the water.
3. Lens distortion: Here, it is necessary to investigate to what extent the strong lens distortion of the videos can be removed. Standard procedures are to be compared with techniques from film matchmoving.
4. Horizontal resolution of the panorama: Here, it is necessary to test which focal length offers an optimum of parameters: future-proof 30K resolution, native video integration, snapping position in the panorama head, and the overlapping area.

More problematic is the projection room. The curtains that cover the windows on two opposite walls are too wavy and produce an inconsistent projection. The next problem is the different types of projectors installed due to structural conditions, which in some places also distort the image. Also, the vertical resolution is no longer up to date. Future developments in the field of graphics cards could help here.

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Author Biographies

Eberhard Hasche received his diploma in electro engineering from the Technical University of Dresden (1976). Afterwards he studied double bass, composition and arranging at Hochschule für Musik „Carl Maria von Weber“ in Dresden (state examination 1989). Since 2003 he is professor for audio and video technology at Brandenburg University of Applied Sciences, Germany. He is focused on image compositing (certified Nuke Trainer by The Foundry in 2012). He is member of the Visual Effects Society since 2018.

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ANNEX A

Figure 27. *Results of the panorama test with seven recording devices*