Advanced Motion Controlled HDR Panorama Time-lapse photography

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Abstract

There's always a fast moving development in the video- and camera technology. Better sensors, lenses and calculating algorithms of the cameras enable the creation of bodacious images. One reasonably new technique is the HDR photography which uses multiple different exposed images to gain the whole dynamic range of what our eye can actually see. The created images are combined in a post production process to a single impressive image.

Another camera technique is the time-lapse technique. At time-lapse, single pictures are taken in a long period of time. These pictures are combined to a movie and show the long period of time accelerated. Sure, this technique is not completely new, but the fast developments in the sector of the DSLR cameras enable many new possibilities in creating time-lapse recordings. The combination of the two above mentioned technologies creates other possibilities to record impressions of the reality in a more interesting and brilliant way. The highly developed DSLR cameras enable the combination of these techniques without any additional equipment. This simplicity and compactness make it possible to develop the time-lapse technique in a way to create more exciting sequences. The use of more than one camera enables panorama photography in time-lapse. The latest developments are moving time-lapse recordings. In most cases the camera is rotated or dollied at a very slow speed. Because of the need of very minimal and extremely precise movements it is very difficult to create constant smooth movements. But exactly that is the future of such films. The movement of a camera creates an impression of the space at which it is pointed at. This thesis takes a closer look at the possibilities in creating HDR, panorama and time-lapse recordings. Possibilities of creating complex movements in three dimensional space at the use of HDR panorama time-lapse is also a topic of this thesis. The difficulties in the creation of time-lapse recordings are getting em-

blazed and a possible production pipeline is developed. To increase the experience of the impressions a way to create panoramic HDR time-lapse with using more than one DSLR- camera is shown. Also a closer look at the post production process in the field of time lapse recordings is given.

1 Introduction

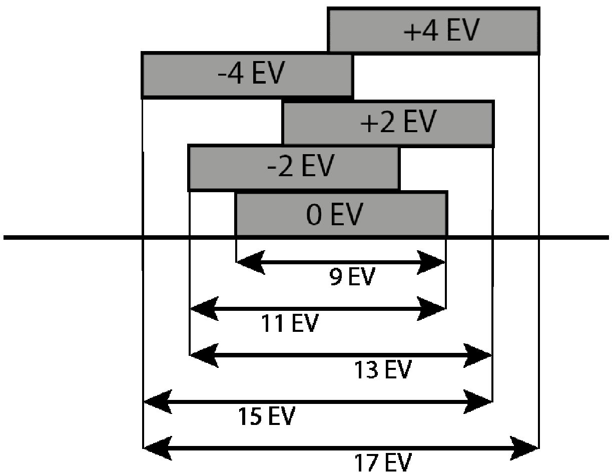
Time lapse recording raised a long time ago. In principle since Eadweard Muybridge invented moving images in 1872. Since then this technique was developed further up to moving time-lapse recordings. Mainly independent film makers and home constructors made important developments and the technique always has been in the fringes although it is used in most documentaries. The time-lapse technique acts like adding to photographs the factor time. If a photograph of a sunset looks nice the impression in time-lapse is comparably more impressive. However the time-lapse sequences are very impressive they may not stand on their own because of the difficulties in the way of displaying them. Like for every other moving images a screen or projector is needed and because most of the time the sequences are quite short they cannot even fill a short film length.

In time-lapse recording there is always the attempt to create more and more impressive images. This can be done by finding more impressive motifs or developing the recording the techniques; or in the best way combining both. If a look at the photography area is taken two major developments have helped to create more impressive images. Firstly the increasing of the angle of vision by creating panorama images and secondly by increasing the dynamic that is the contrast range of an image by creating HDR images. In time-lapse evolution HDR is already common, panorama images are rarely seen. The combination of these two may be a further development step. Another approach is to add camera movements to the time-lapse recordings. This also helps to create impressive sequences. Always at combining and implementing new techniques and technologies there occur a lot of questions and problems. This paper will take a closer look at these and tries to finds some answers and solutions. The paper is divided in four major chapters which take a closer look at the techniques which help to create more impressive time-lapse recordings.

2 High Dynamic Range Imaging

There is always the challenge to shoot more and more impressive images of the world in front of us. The evolution of photography does not stop in our time. On the contrary, it seems that the development moves on faster as it did till now. One of the many different popular techniques in photography is the use of high dynamic range, so called HDR, images. This is not a very modern technique; In fact it is more a compromise in the area of digital photography because the lack of dynamic appeared that strong just by the use of digital photographic sensors. But at first, what is hidden behind high dynamic range images and why are they used?

The dynamic range of an image describes the distance between the darkest and the brightest value in the image. These density values have to be stored in digital units. One pixel of a digital image has three colour channels: red, green and blue and for every channel the density values have to be stored. In a JPEG compressed image it is possible to store 256 different values for every channel. That matches maximal 8 bits per channel per pixel. And this is strictly speaking in most cases way too less to display the whole dynamic range of the real motif. This way of displaying an image is called LDR (Low Dynamic Range). High dynamic range images feature a higher count of bits to store the density value and allow a much more precise display of them. They have 32 bits per channel reserved for storage which are 4 294 967 296 brightness values (Held 2008, p. 12).



Picture 1 Anatomy of a sequence of exposures for a HDR image

In picture 1 the images which are taken for a HDR image with 17 exposure values are shown. In this example, with the use of 9 EV, to reach a dynamic range of 17 EV, five pictures have to be made. To reach a contrast range of 9 EV in an image, the use of the RAW format is necessary and this leads to very large files and a lot of unnecessary data.

Post processing of HDR footage

After creating the suitable exposure sequence, the different sub-images have to be combined. This creates a 32 bit image. A 32 bit image cannot be displayed right at a computer screen or any other presentation device so the whole information has to be compressed to a 8 bit image again. For this there are several methods which are suitable for specific purposes and none of the different methods can be declared as the best one. All methods base on the fact that the HDR image has to be suited to a LDR image for presentation. These methods are combined in the area of tone mapping, which means reducing the three colour channels from its wide 32 or 16 bit bandwidth to a small 8 bit bandwidth.

In the area of time-lapse there is another important way of dealing with HDR footage. In this third way, the 32 bit image is not treated like a 32 bit image instead there is chosen a specific 8 bit range of the 32 bits to control the exposure seamless from one image to another – like in the first tone mapping algorithm "Exposure and gamma".

Tone mapping

Tone mapping is a method to reduce the dynamic range from an HDR image to a normal LDR (Low Dynamic Range) image. It can be done in several different ways, some of them are listed below.

- Exposure and gamma
- Highlight Compression
- Equalize Histogram
- Local Adaption
- Details Enhancer
- Tone compressor

These different mapping techniques compress the bandwidth in different algorithms which create slightly different results. To define one method as the best one is not really possible because for different approaches different algorithms fit better.

Fusing

Fusing is a technique for displaying HDR images at LDR-devices. It is not a tone mapping operator, it stands on its own and uses other algorithms.

> We propose a technique for fusing a bracketed exposure sequence into a high quality image, without converting to HDR first. Skipping the physically-based HDR assembly step simplifies the acquisition pipeline. This avoids camera response curve calibration and is computationally efficient. It also allows for including flash images in the sequence.
>
> Our technique blends multiple exposures, guided by simple quality measures like saturation and contrast. This is done in a multiresolution fashion to account for the brightness variation in the sequence. The resulting image quality is comparable to existing tone mapping operators.
>
> (Mertens, Kautz & van Reeth, 2007, p. 382)

Exposure fusing enables creating HDR images without the detour to 32 bits and back with tone mapping. So in this workflow the way of creating a 32 bit image is not needed which saves a lot of memory and will reduce the processing time. Image 13 is created by exposure fusing. In comparison to image 14, which is created by standard tone mapping operators the exposure fused image is sharper than the tone mapped ones. Also the contrast is more balanced. These benefits are very welcome in the field of time-lapse recordings.

3 Panoramic photography

The modern technology makes it easy to create panoramic pictures – it is even possible to create panoramic images with a Smartphone camera and a special app. Also many digital consumer cameras have the possibility to shoot and create panoramic images but these functions deliver most of the time not really great results and cannot be compared to images which are created by many different images which are in high resolution and combined with special care.

3.1 Recording techniques

To create a panoramic image there exist several different techniques. First of all the purpose of the panorama has to be defined. Is the picture used for an interactive presentation or high resolution prints. The main similarity of all techniques is the use of the nodal point.

> Die Einzelbilder eines Panoramas werden alle von einem bestimmten Punkt ausgehend aufgenommen. Um Fehler beim späteren Zusammenbau der Einzel-

> bilder zu vermeiden, wird die Kamera auf einen zentralen Drehpunkt, der Nodalpunkt, ausgerichtet. Dieser Drehpunkt muss exakt der optischen Bildachse entsprechen. (Woeste, 2008, p. 23) [1]

Rotating around this nodal point the camera takes pictures of every desired angle and later these images are combined to one large picture. If this nodal point is not adjusted, a parallactic deviation occurs which makes it hard to combine the images seamlessly in the composition production step. For this technique a special device which enables the camera to rotate around it's nodal point is very common.

The number of necessary images depends on the camera lens and the angle of view. If the needed angle of vision is very large, many images have to be shot and also when the used camera lens has a high focal length more images have to be taken. The upper extreme is to use a fisheye camera lens and shoot exactly two images to get a view of 360 degrees but this has many drawbacks such as extreme bended lines and inaccurate edges at the combining areas. The best result delivers a compromise of focal length and number of taken pictures.

Table 1: number of necessary images for panoramic imaging

HFOV	Number of images (exact)	Number of images (rounded)
60	1,25	1
80	1,667	2
100	2,083	3
120	2,5	3
140	2,917	3
180	3,75	4
200	4,167	5
220	4,83	5
240	5	5
260	5,417	6
280	5,83	6
300	6,25	7
330	6,875	7
360	7,5	8

1 The single images of a panorama are all recorded from a specific point. To avoid errors at the combining production step the camera is calibrated to it's central spinning point, it's nodal point. This pivot point is exactly the optical image axis.

The approach above is the fastest and simplest way to create panoramas in s horizontal way. The panoramas which are created with this technique are very wide and have little height. This makes it difficult to present it at a screen or something with a fixed aspect ratio, so there occur lager black areas on a TV screen when such a panorama is displayed at a screen with 19:9 aspect ratio.

Picture 2 presentation of a panoramic image on a 16:9 screen

3.2 Montage of panoramic footage

After shooting the footage for the panoramic image, the single images have to be combined to one large panorama image, most of the time this is done by software algorithms. Many of them work without human interaction. The panorama stitching operator in Photoshop only asks the user one single question and does the rest of the operation without interaction. For stitching a panorama there are four steps to consider.

- Optical compensation
- Transformation
- Positioning
- Rendering and blending

These steps are necessary to create a well looking panoramic image. Like mentioned above normally these steps are done by software algorithms nearly completely automatically and in consideration of time-lapse recordings this is necessary because the amount of data which is created for film sequences is enormous. Keeping in mind the sequence need only software which is able to stitch panoramas in batched mode with the same adjustments is suitable and this decimates the number of software products quietly down, or even makes it necessary to stitch panoramas manually.

3.3 Problems in combination of HDR- and panoramic imaging

Every technique if it is HDR imaging or panoramic imaging, has it's own difficulties and may create images with insufficient quality. It is very important to respect every creation step and try to get the best footage possible. Every processing step can introduce new faults and may make image unusable. One mayor problem in combination of different techniques is always the lack of the possibility in processing the different source materials. That problem occurs if the used software is not able to handle the material or is simply not built for that. So in the case of combining HDR and panoramas this is exactly the case. Most panorama software is not able to handle 32 bit image files so one way would be to avoid that the panorama software gets 32 bit images delivered by processing the single exposures first the panoramic images and then to HDR or simply create a new own workflow. Finally the consideration of batching the combination also has to be made in aspect of the volitional time-lapse processing possibility.

4 Time-lapse

The word time-lapse is defined by following description in the oxford dictionary:

> Denoting the photographic technique of taking a sequence of frames at set intervals to record changes that take place slowly over time. When the frames are shown at normal speed the action seems much faster.[2]

This means that a sequence of pictures taken by a photographic camera in a longer period of time is combined to a movie strip. This enables the viewer to make hardly seen actions, like growing procedures of plants, visible for the human eye. The goal of such recordings is to create impressing images of the nature. At first glance this seems pretty easy, but at a closer look there is a

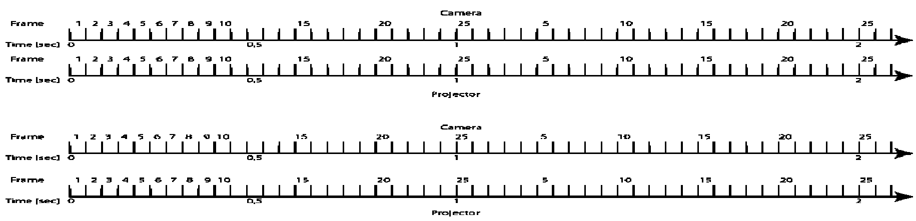
2 http://oxforddictionaries.com/definition/time-lapse?q=time-lapse, last visited 9.4.2012

special need of precision and requirements to the photographic cameras and their accessories. This section of the paper takes a closer look at the principles and techniques in time-lapse. Furthermore the problem of creating camera movements in time-lapse recording is going to be discussed.

In time-lapse recordings the value of the speed is main focus. At recordings with common methods the question of speed is secondary because a normal camera is focused to shoot in real time. These recordings normally are played back in real time or sometimes are forced in playback to different speeds. But this decision normally is made in the post production process. Not considered in this area are slow motion recordings, such shootings have to be planned very well to get useable material.

Continuative to the speed issue, the movement of the motif and the environmental circumstances have a huge impact in the result. Every part which has impact of the taken pictures has to be considered and planned before a recording can start, and such recordings can last for days or months.

4.1 Functional principle



Picture 3 creation of time-lapse recording

The first timeline in the picture above shows the camera which records in 25 frames per second mode. The projector in the second timeline plays the recorded sequence also in 25 fps, which enables realistic natural movements. Timeline number three shows the camera in "time-lapse mode", only every sixth is recorded, which means that there are four frames per second. The last timeline shows the projected frames. The projector works in 25 fps which compresses the material from the camera and plays it six times faster than it really is. This is the basic principle of time-lapse recordings. This image describes the creation of time-lapse recordings which are made by a movie camera, in fact most time-lapse recordings are made by digital photo cameras because most of the time the recording duration is way longer than the longest possible recording duration of film cameras or it is simply not necessary to shoot by film camera.

4.2 *Recording methods for time-lapse sequences*

Basically the recording method for time-lapse sequences is pretty simple. A camera has to be connected to a timer. This timer has to be set to a suitable value for the images and the real time moving and then the recording can be started. During the shooting it is important to take care that no mechanical influence to the camera occur which might change the cameras position. Changing the camera angle, it's position or simply any value will make it unable to create a smooth movie sequence. Because human eyes are trained to recognize the smallest movement, it is very important to take extreme care of controlled camera positions and attachment.

According to the different requirements three types of creating time-lapse exposure can be derived:

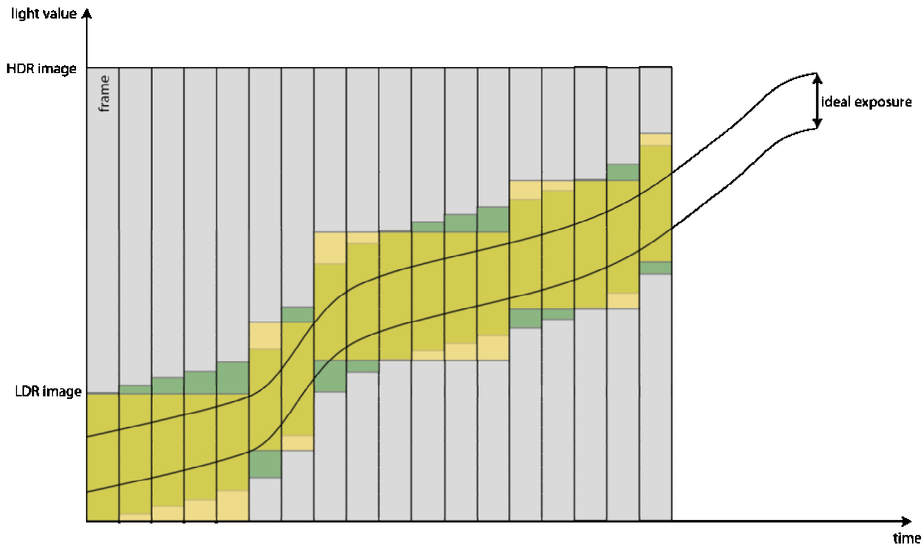
1. Single exposure
2. Exposure sequences for HDR processing
3. Bulb ramping

Single exposure

This is the easiest way to create time-lapse recording. Motifs and environments which do not change their illumination dramatically and do not need a very high amount of contrast resolution are shot in single exposure time-lapse. The best way is to switch the camera into the manual mode, create a reference image and adjust the camera setting that they fit for this reference image. Are the adjustments made, the time-lapse recording can begin.

Exposure sequences for HDR processing

Exposure sequences for HDR processing are suited for motifs which need a high contrast reproduction or such with big differences in the illumination. The high exposure bandwidth can be used in two different ways, first for HDR processing and further tone mapping or fusion and secondly for smooth transitions between exposures. If a non tone mapped LDR image is needed the creation of an exposure sequence and the following 32 bit HDR image processing is a good workflow for creating well looking LDR results. Against the system of changing the values for the exposure at the camera itself the 32 bit images are treated like 8bit images. After creating a 32 bit image sequence the desired exposure range which fits in the 8 bit range can be chosen and exported. This creates smooth transitions between two different exposures and avoids flickering – one major problems in shooting LDR time-lapse recordings of sunset and sunrises.



Picture 4 illustration of single exposure, exposure sequencing and bulb ramping

In picture 4 the different techniques of dealing with changing illumination is shown. Such an illumination curve may occur at a cloudy sunrise. The grey area indicates the contrast range of a HDR image. The yellow and green areas show the contrast range of LDR images. For displaying until now the images have to be converted to LDR to display them and so with the use of HDR images it is possible to either compress the recorded HDR image by tone mapping or simply choose an exposure in a range of a LDR image. These exposure ranges are not defined or staged by aperture, ISO or exposure time values; it can be chosen continuously which avoids flickering. The yellow parts indicate that continuous adjustment of exposure values. This is a very exact method which creates really good results but it is also very memory intense. The green fields indicate the blub ramping method which is described in the next section.

Bulb ramping or blamping

Bulb ramping is a method in which the exposure is adjusted to the actual illumination of the motif. The actual light setting is measured and the cameras exposure time, aperture and ISO gets adjusted to it. This works like if the camera is set to the automatic shooting mode. Good programmed bulb ramping algorithms do not change the exposure values in too big steps, they control the exposure according to the images which have been shot before and try to smooth the exposure differences. The bulb ramping technique saves a lot of memory space but due to the construction of a digital camera it is not possible to create complete smooth time-lapse sequences. Newer algorithms get better all the time but finally if the settings at the beginning of a time-lapse recording are wrong the whole sequence may be wrong. Using the HDR method instead makes the recording process easier and transports sensitive production steps to the safe post production area.

5 Combination of HDR, panoramic and time-lapse recording

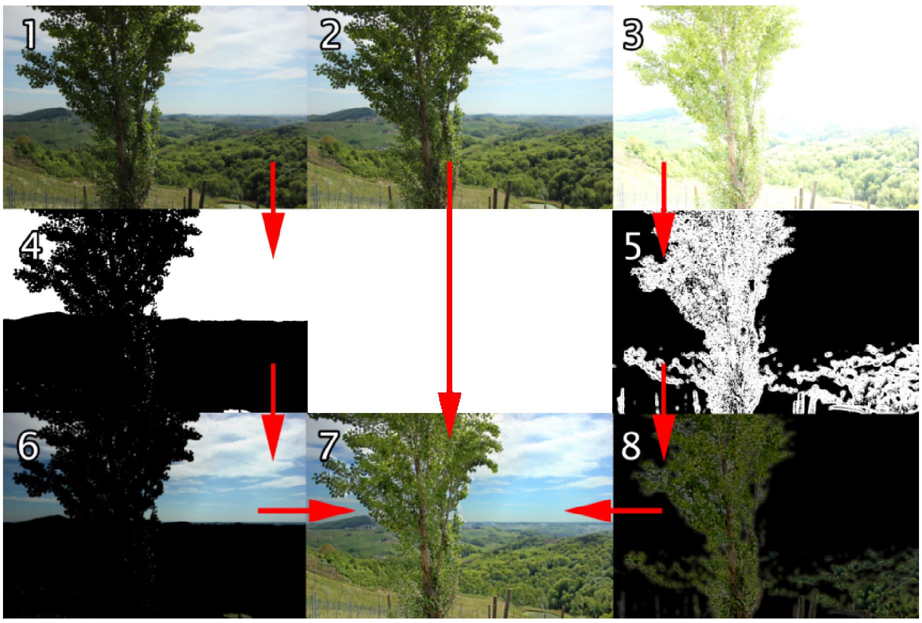
The combination of all the introduced techniques creates many intricacies. Most software is not suited for combining panoramic images and HDR and furthermore creating movie sequences. Sometimes batch operations are implemented but then a satisfying HDR workflow is missing. This leads to the way of creating an own workflow. This chapter introduces such a specific workflow which enables it to create HDR panoramic time-lapse movie sequences.

There are several different production steps in the handling of HDR panoramic footage. Based on the different steps of each technique these can be scheduled in many different ways. Summing up there are following steps consider:

- Shooting footage
- HDR processing
- Optical compensation
- Positioning transformation
- Time-lapse processing
- Tone mapping
- Rendering

Implementing the workflows for batch operation

Principally every workflow can be implemented in modern compositing software. In this paper the example of the last workflow is shown in “After Effects” because it seems to be very fast and auspicious. Compositing software is built for batch processes so no problem will occur in that field. The first considerations have to be made on how to implement the different steps in “After Effects”. Until now no really good workflow for tone mapping in “After Effects” is present but in the simplest way a global tone mapping scene can be built with the help of some luminance keys and layer masks. For testing purposes a panoramic image which consists of four panorama images in the horizontal direction and each image again consists of three exposures for high dynamic range is used. The first step is to create a workflow for simple HDR tone mapping. Here three different exposures are provided, one underexposed, one correct exposed and one over exposed image.



Picture 5 global tone mapping workflow

The global tone mapping operator uses the parts of an image which is best exposed. So in the example of the three images the normal exposed image will be the fill-ground. Every part which is not filled by a better exposed one will be covered by the normal exposed one. From the under- and over exposed image the well exposed parts are separated through a mask and finally everything is combined to a global tone mapped image. In picture 5 part 1 the sky of the underexposed image is separated through a luminance key (4) and the result is shown at part 6. In part 3 the brighter exposed parts like the tree in the foreground are also separated by a luminance key from the background. Finally the keyed images (6, 8) are combined by lighten or multiplying to the fill-ground (7). This workflow delivers good results, is fast to calculate and easy to implement so it fits perfectly for testing purposes. This workflow can easily be done in a batched mode.

The next step is to set up a scene for combining the panoramic footage. For this After Effects offers a 3D workspace so it is possible to arrange the images in 3D space as they have been place while shooting. A further camera grabs this new image and the panorama is stitched “automatically”. By changing the position and rotation of the images in 3D space the pictures can be fitted together. To compensate the lens distortion a “optics compensation” filter is applied to every image. Finally the images have to be adjusted together to fit in the colour spectrum and then the batch for the panoramic HDR image sequence is finished.

6 Camera movement in time-lapse photography

Until now every discussion of time-lapse recordings dealt with a non moving camera but every technology is growing and so the next development step is to introduce camera movement in time-lapse recordings. Compared to the movement of a normal camera shot the motion in a time-lapse recording is much more complicated because of the immense compression of time. For example there is no problem to record a freehand motion with a normal camera, in time-lapse condition such a free-handed motion would only create a crappy chatter. Motion in time-lapse photography has to be very accurate and carefully planned. It is very hard to estimate the final speed of the movement when the time is getting compressed at such high rates. So a accurate calculation of the resulting motion is required.

Different types of movements

Principally movements can be divided into three categories, firstly motion in one dimensional space, secondly motion in two dimensional space and thirdly motion in three dimensional space. Additionally there are movements around the own axis possible.

A movement create by a dolly would be a motion in one axis, it only two directions are possible – forth and backwards, up and down or left and right. Adding more axis the movements get more complicated up to a three dimensional movement and the possibility of spinning the camera around all different axis.

Until today two mayor movements can be found in time-lapse sequences. The most used motion is a rotation around one axis. Therefore existing some special rotation devices which are able to turn the camera in very small steps like 0,5 degrees or less.

The Standard Rotary Table can be programmed to move in increments as small as .0125 degrees or as large as 360 degrees between exposures.[3]

Such small rotations are necessary to create a smooth motion in the final sequence. Larger rotations would cause a choppy image sequence and a wrong result.

The second popular mode of motion is the pan or dolly. Here the camera is moved a very low speed along a track. Mainly this is a straight track – so the motion is only in one dimension.

If a closer look is taken in the movie production area following equipment for movements are common:

1. Dollies
2. Steadycams
3. Jibs and Cranes

Dollies have been discussed above and create only movements in a one dimensional space. The complete opposite are steadycams. A steadycam is a stabilized camera which is able to move in all directions. The steadycam-operator, a person who is connected to the steadycam-rig, controls the camera. The operator can walk around and the balancers stabilize the camera to create a smooth movement. This works great for recordings which are made in real time. Time-lapse recordings with the help of a steadycam are not possible because the camera movement is way too fast and imprecise. The operator is not able to control the camera as slow as it is needed for time-lapse recordings. The third type of camera movement equipment are cranes and jibs. Cranes have a longer boom than jibs and so they create a larger movement. Both, cranes and jibs are built for creating impressive fluent motion with a wide range. Because such long movements hardly are made in a very

3 www.bmumford.com/photo/rotary/standard.html, last visited 16.05.2012

slow speed they are not precise enough for creating time-lapse recordings. So there is nearly no possible device from the film area which suits for time-lapse purposes.

Another approach is to look at the field where precise movements are essential. The assembly line production is a very good example where precision and accuracy is needed and nowadays nearly every production step of an assembly line is executed by a robot. Robots are built to make precise movements and can stay exactly in a desired position.

Robots can be classified in four different categories

1. Industrial robots
2. Service robots
3. Field robots
4. Humanoid robots

Humanoid robots are built to be as human as possible so they are not really su itable for precise and accurate movements. Service robots are usually built fo r a specific duty and often only are suited for limited planar motion so they are also not useable for free three dimensional movements. Field robots are also built for a specific purpose and are not prepared for changing duties. The only suitable class of robots is the industrial robots class. These kind of ro- b ots are built to exercise many different duties, are able to change their tool and can fulfil precise and accurate movements in all directions.

7 Conclusion

Summing up, every technique which is combined with another introduces new problems. There is a rapid development in film cameras which are able to shoot HDR but the technology is far from perfect. Generally the field of moving HDR images underlies in a very fast development. Major focus in the field of moving HDR images is the creation time. Exposure bracketing needs a lot of time and limits the final frame rate. For this other ways have to be found. Further the displaying methods of HDR are not up to date anymore. Although the combination methods like tone mapping or exposure fusing get better every day this are still 8 bit images and it is not possible to display the whole dynamic range. If better displays are provided the image quality of time-lapse recordings will increase. In the area of panorama photography the same circumstances appear. Usually the creation of panorama images is a rather simple challenge, by adding the factor time to that it gets quite complicated. Stitching and problems in the parallax which normally do not appear make the whole process complicated and error-prone. The nodal point problem at the use of more than one camera limits the final quality of the panorama image. Further the combination of HDR, panorama and time-lapse recording also creates a lot of problems because the common post production software of each specialty is not written to handle data which is suited for other working areas and also nearly no software includes a batching operation possibility. The implementation of HDR and panorama in up-to-date compositing software is in the fledgling stages and a further development can be expected. The main problem in the development of time-lapse recording is that big companies do not really support this technique. Most inventions for time-lapse recordings are made from amateurs at home in their tinker cellars but the possibility of creating more impressive recordings is boundless. The main development beneath HDR and panorama will be the motion controlled time-lapse recording. Like in the history of film, moving the camera in three dimensional space heralded a new era and maybe the same will happen in time-lapse. The potential for development is huge and the results will deliver unseen images of our environment. But not just the simple displaying of time-lapse recordings is the only way to use such sequences. One application area would be the area of computer generated images especially for rendering. With 360 degrees HDR images digital 3D scenes can be illuminated in a very realistic way. Using 360 degrees HDR time-lapse recordings introduces the factor time into the illumination of 3D scenes created in the computer, that enables more impressive and realistic renderings.

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