DIGITAL COMPOSITING IN THE
VFX PIPELINE

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ABSTRACT

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The purpose of this thesis is to explore a specific area of visual effects production - Digital Compositing. The work explains the origin of this craft and clarifies reasons for its demand in the field.

The theoretical section explains the role of Digital Compositing in the VFX pipeline, as well as introduces a reader to the major compositing operations, which digital artists in the field have to be able to perform. Among those are compositing CGI materials into live-action plates, rotoscoping, keying, clean up, tracking and recreation of realistic lens effects.

The practical part demonstrates how those Digital Compositing operations are combined on practice to achieve a desirable illusion in a shot.

Based on the ability to produce realistic illusions and implement complex visual ideas, the works concludes, that Digital Compositing is an important and inseparable part of the VFX pipeline, and a demanded craft in the industry.

CONTENTS

ABBREVIATIONS AND TERMS

CG	Computer Generated
CGI	Computer Generated Imagery
Denoise	The process of removing digital noise from a plate
DOF	Depth of Field
Matte	Mask
Plate	Live-action footage, shot by a camera
Rotoscoping, Roto	Frame by frame masking process
VFX	Visual Effects

1 INTRODUCTION

Digital Compositing is widely used in the VFX production today, whether it is TV commercials, music videos or feature films. The goal of this process is to seamlessly combine two or more images or sequences of images into one. In other words, it can be said, that the core idea behind compositing is the idea of visualizing events that never took place in the real world. Literally speaking, faking the reality.

The need to show something to the audience that has never happened came to artists even before feature films appear. One of the most significant examples of that is the work of a Swedish photographer Oscar Gustave Rejlander, produced in 1857 and called "Two Ways of Life".
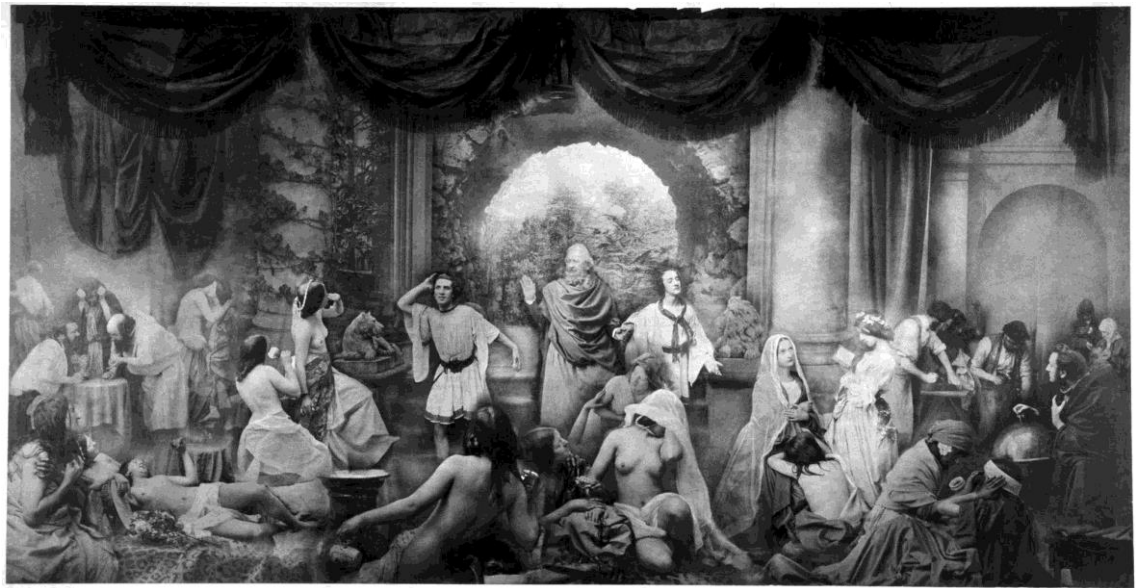

FIGURE 1. "Two Ways of Life" (Rejlander, O.G. The Father of Art Photography, 2013)

Despite the fact, that this image has no unrealistic objects, as movies do nowadays (robots, fantastic machinery, etc.), in that time production of such complex photograph was extremely complicated. The artist should have had a studio of a great size, wide number of lighting equipment and above all, all the characters should have been frozen in their poses for too long for a photographer to build and lighten a flawless composition. Nevertheless, Oscar G. Rejlander came up with a solution. He separately photographed different characters or pairs of characters, making it possible for himself to lighten each

of the separately as well as scale them in according to his vision of the final work. After that, he exposed selective parts of different films to one piece of paper, eventually, making a composite of several images, bringing them into one "world", making an illusion that all those characters have once happened to be together in one room and interact with each other.
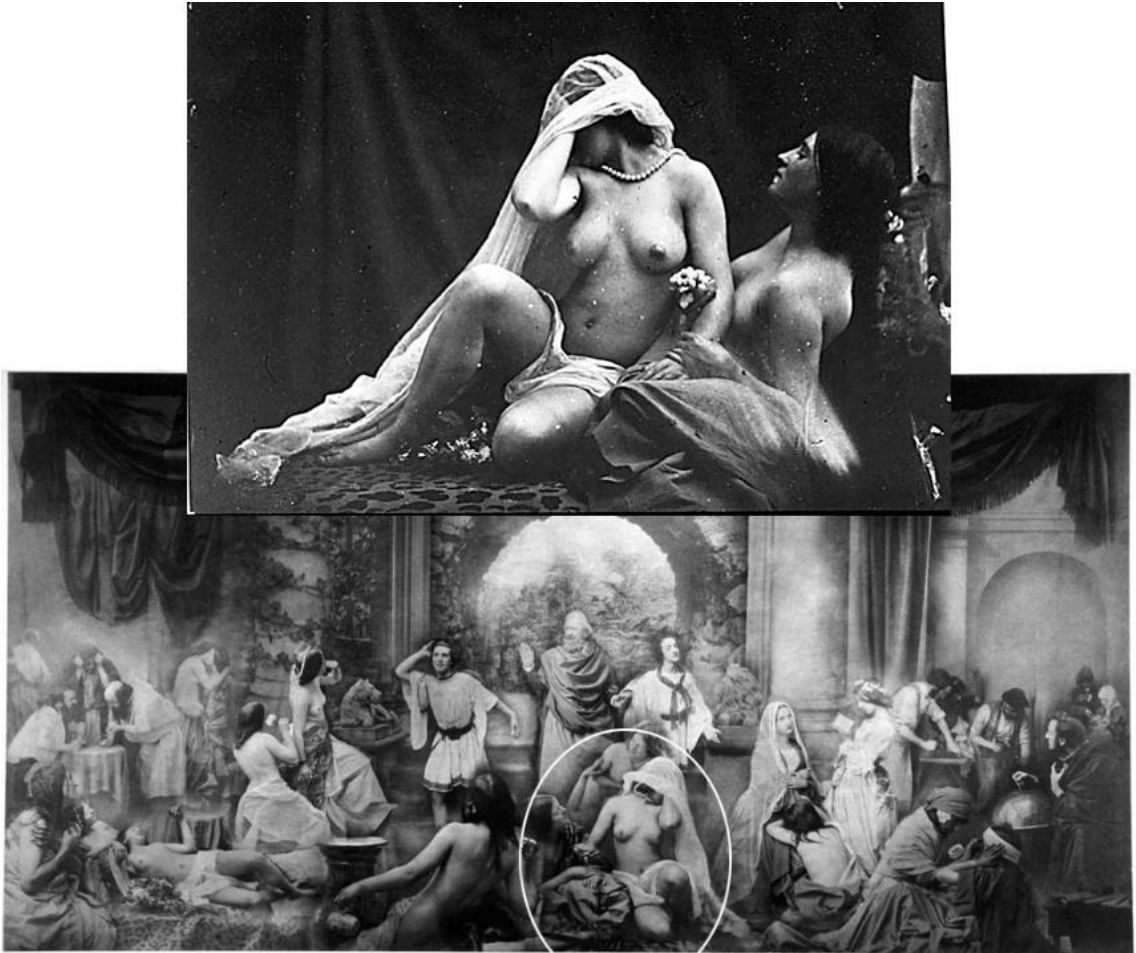
FIGURE 2. One of the fragments of the work, which later became a part of the final composition (Rejlander, O.G.: Two Ways of Life, 2008)

What Oscar Gustave Rejlander did was named "optical compositing" and later had been widely used by many artists in photography and in motion pictures as well. And one of the ground-breaking examples of compositing different elements into one moving scene is a short movie produced by Georges Méliès. ("Four Heads Are Better Than One", Méliès, G. 1898).

Georges Méliès used a slightly different technique because of the difference between photography and moving pictures production. When shooting the head that were supposed to be located on the table, he blacked out the rest of the image by shooting the glass covered in black paint, so that, these areas of the image would not be exposed on the footage of the final composite (Hollywood's History of Faking it, FilmMakerIQ,com). The success of the movie was enormous. People enjoyed the fact that they literally saw something on the screen, which they logically knew, was impossible to happen in reality.
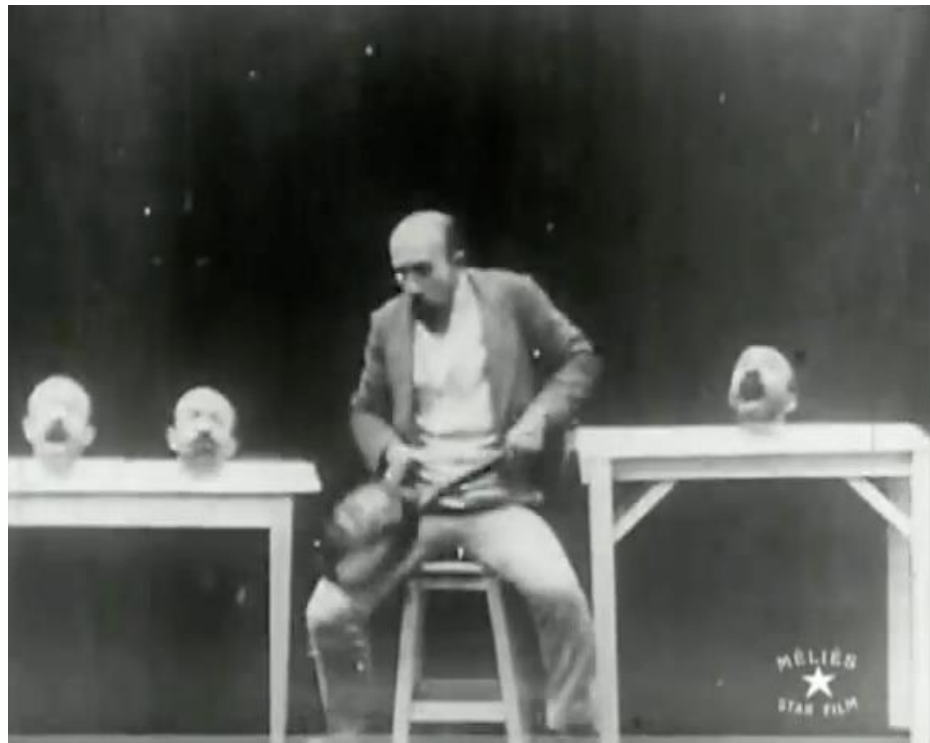

FIGURE 3. A still from the movie "Four Heads Are Better than One" (Méliès, G. 1898)

Optical Compositing were applied in other movies that became turning point in the history of cinema, such as "King Kong" produced in 1933, "Godzilla" of the year 1958 and even "Titanic", made in 1997.

Optical Compositing had the same exact purposes, which Digital Compositing has – to unite two or more images into one seemingly photo-realistic image. The only difference is the progress of technology. What had to be done by hands before (blacking out part of the image that should not be in the composite, like in the "Four Heads Are Better Than One", for example), now with the appearance of computers and dedicated software is done digitally.

Each movie that comes out on the cinema's screen these days has a big percentage of compositing work involved. One of many examples that prove the importance of being able to fake the reality in cinematography is the movie "War of The Words", made by the Paramount Pictures and Dreamworks in 2005, and based on the eponymous science-fiction book.

FIGURE 4. Still from the movie "War of The Words", 2005 (Image courtesy of Industrial Light & Magic)

The still image from the movie shows that a viewer sees a robotic alien walking right through city centre. In order to produce this kind of shot, 3D modellers need to create a robot first. However, it will not be enough to "sell" the illusion. 3D materials that just came out of the 3D software exist by itself, they are not integrated in the shot, they have different lighting, reflection, shadows, etc. compared to the real footage. And this is exactly what the purpose of compositing is – to integrate one image into another one and make them look like one whole. So that the image looks real, even though the audience knows de facto that these events never took place in reality.

This process of integration includes many steps and techniques. The majority of them will be discussed in this paper. But before that, there is no better example to demonstrate those techniques, the purpose and the results of Digital Compositing than the video made by

Brainstorm Domain. It provides a video breakdown of the visual effects made for the second season of the TV show "Boardwalk Empire" released in 2011.

FIGURE 5. A still from the video breakdown of "Boardwalk Empire" Season 2, 2011.

There is no doubt that Digital Compositing plays a crucial role of today's production of visual effects. While being a form of art, the art of creating a perfect illusion, it still remains a highly technical craft, which involves the knowledge of various digital software and processes behind it.

WHAT IS DIGITAL COMPOSITING

1.1   The value of Digital Compositing

Even though the need to compose different imagery elements into one has been in demand even before the digital age, the specific, dedicated tools for that purpose did not enter the post-production market before mid-1990s. The first compositing application with a node graph architecture (see p.13), Shake, was released by Sony Imageworks in 1997. Since then compositing applications have rapidly became inseparable part of the VFX pipeline, affected by evolving storytelling and the demand for fantasy in those stories.

One of the major reasons for that is money. If production costs are reduced, so grows the profit. Compositing applications are a sort of continuation of 3D applications and the combination of using both kinds of software, apart from giving more control from the artistic perspective, saves a company lots of machine power, render times and consequently production time. And in a production of any kind and any scale the equation is immutable – time equals money.

The popularity of Digital Compositing can be also explained by the fact that the vast number of modern movies, games, and TV production have fantastic elements – fictional characters, aliens, space ships, imaginary environments, etc. Having these elements raises a need to involve technologies and techniques that Digital Compositing provides.

If an element of the scene does not exist in reality it needs to be computer generated. Which means that 3D modelers, textures and lighting professionals build those graphical elements in the specialized software. While visual effects are made by VFX artists, production team shoots background plates and realistic elements. Afterwards, compositors bring all of those elements together into one whole. If the whole scenery of the movie is fictional, 3D professionals create those as well and compositors fake the illusion of realism for a shot or its elements (CG rain, snow, sky replacement, etc).

However there is even more to that. Not only does Digital Compositing improve the efficiency when working with CGI, it also facilitates production of the real live footage. For example, a shot of a helicopter that flies over the snowy mountains somewhere in Alps.

The difference in financial investments are hard to deny. On one side it is the necessity of a shooting team, travelling time and costs, renting of a helicopter and many other expenses. On the other side it can be all done in one room by two-three people over a few days' time. The process is already familiar – creating high-quality 3D and realistic compositing of a scene.

Apart from "faking" real-life footage, compositors also contribute significantly in a preparation and improvement of the existing footage. Among others they perform clean ups of wires and rigs; deleting tracking marks from the actors; combine several live footage elements in one; fix, often inevitable, mistakes captured in a frame.

Nowadays the biggest part of a production of, for instance, an action or adventure movie takes place in a post-production facilities. The advantages that digital work environment brings into the process are limitless. The most significant of them are: full control of the materials, the ability to change creative decisions on any stage of production, saving production times and costs.

1.2   Digital Compositing in the VFX pipeline[1]

Because of the nature and purposes of compositing, specialists of this area come into the pipeline relatively late – Figure 6. For instance, when characters design is developed and approved, when 3D models are completed or almost completed, when all the necessary footage has been shot.

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[1] VFX pipeline – the workflow of visual effects production, the organization of this process.
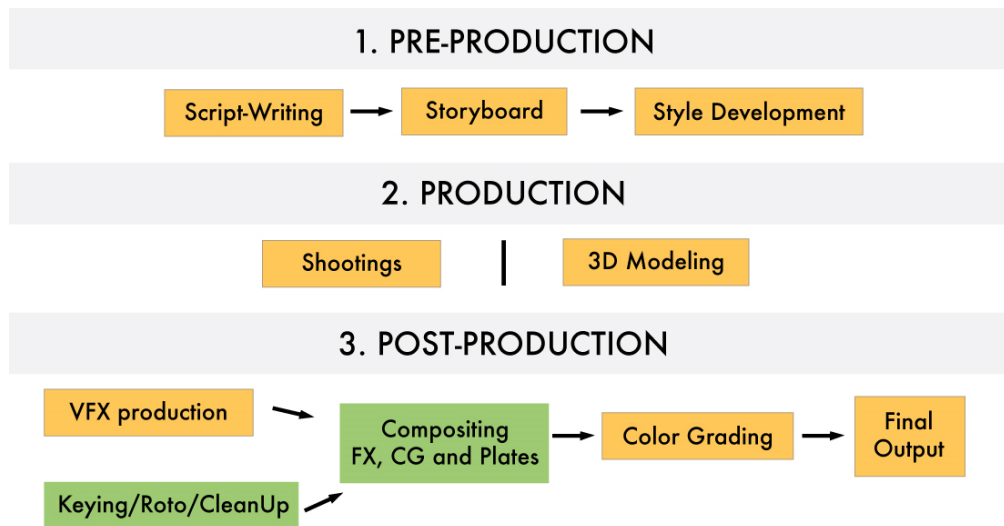
FIGURE 6. VFX Pipeline (Ostasheva, A. 2015)

It is discussable whether compositors invest any creative intellectual property to the shot. This is because they work with materials provided to them by different departments. And the final look of the shot is often defined during the earliest stages of production by an art director. It is worth remembering though that the technical decision-making plays a big role in the process of compositing and often it is the compositors who, using their set of tools and skills, are able to find solutions and resolve critical problems that may appear in a shot.

Figure 7 presents a comparison of how an image looks when it just comes out of 3D software (A) and how it looks after it has been composed (B).
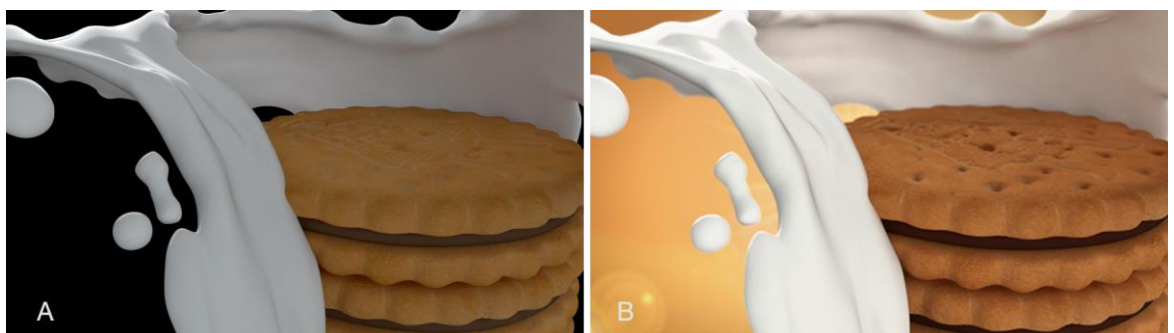

FIGURE 7. An image before and after compositing operations (Ostasheva, A. 2012)

It was mentioned above that a 3D application doesn't have the ability to achieve such level of realism as compositing applications can. In this particular example, the shot was not even meant to be completed in 3D software. There are several reasons for that.

First of all, Figure 7 is just a still image from an animated shot. This particular shot has about 100 full HD frames. And as it usually happens, one shot is just a part of a sequence of several fully or partially CG shots. In according to my personal calculations, render time for a single frame of this sequence in 3D application took approximately 1,5 minutes. After a further calculation (90 sec x 100 = 9000 sec = 150 min) it becomes clear that about 2,5 hours are needed to render the whole shot. After that, the background, lighting and lens effects have been added in a compositing application. Render time for a shot at this stage took about 10 minutes.

Taking that into consideration, it becomes easier to see the justification for compositing appearing into VFX pipeline. As it often happens, the client sees the first version of the produced graphics and decides to change it either a bit or drastically. If those changes involve camera animation or simulations, shapes of models, then there is no way to avoid re-rendering it from 3D application again. However, in case those changes touch the color of the background, lighting of the scene, lens flares and general look of the shot, it all can be done in a compositing application and re-rendered with the least time possible. Considering the strong possibility that those changes need to be applied to every shot of the sequence, the difference in render times becomes more and more significant even for this simple example. It becomes crucial when talking about dozens or hundreds of shots for a feature film production.

Secondly, 3D applications may simply not have necessary tools for creating realism. Especially, when it comes to film grain, atmospheric and lens effects.

1.3   Node-Based vs. Layered-Based System

The craft of Digital Compositing and specifics of its tasks have introduced the whole new approach to the image manipulation – the node-based system. This system is opposed to the layer-based one. Both have their advantages, however it is hard to deny that the node-based system was a true evolution of the image editing process.

A node can be represented differently depending on the particular software. It may have a shape of a circle of rectangle, can be connected to other nodes vertically or horizontally.

The purpose and processes behind it, however, remains the same. Any node receiving a signal alters this signal according to its function and outputs the altered signal.
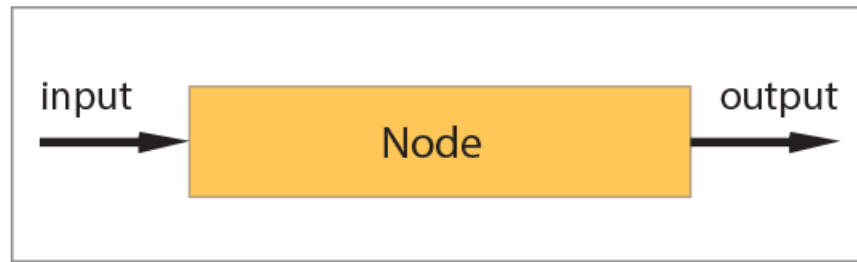

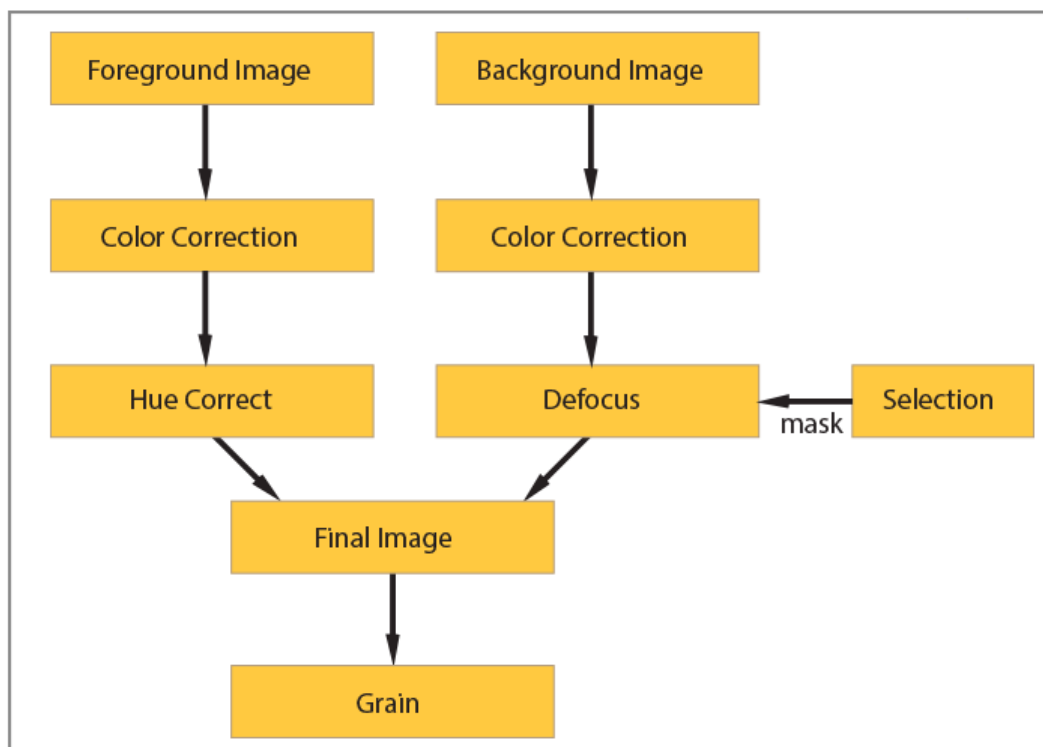
FIGURE 8. An illustration of a node.

FIGURE 9. An example of a node tree.

When several nodes are applied to an image, they form a node tree - Figure 9. And it may get rather complex. The positioning of nodes is not restricted by the software, providing an opportunity to a composer to organize a project in according to his/her preference. In reality, a composite of a single shot may require up to a few hundred nodes – Figure 10.

The key principle of node-based compositing – each element of the shot (foreground elements, middle ground elements, background elements, etc.) can be treated separately before being merged with other elements of the shot. For instance, when integrating a CG element into a footage, a compositor needs to apply different kinds of color correction to

those elements. He can boost up a contrast of the background with one node, and match up black and white point of the CG element with color corrected background by another node and each of those nodes will affect only those elements of the shots, which they need to affect. Other corrections may be added to the whole image after the foreground and background elements have been merged. For instance, grain, lens distortion, chromatic aberration and others.

FIGURE 10. An example of a real-life node tree inside of NUKE.

(Ostasheva, A. 2014)

Apart from that, any node can access and selectively affect specific channel or channels. A composer can also create additional channels inside one image composite for diverse purposes – it can be a saved selection or a mask itself. The node-based compositing system provides the easiness of channel access which has been never accessible before.

The specific trait of this system is based on the fact that every single effect can be manipulated precisely. As Figure 9 shows, every effect assigned to a specific element of an image can be controlled by additional functions, such as, among others, masking by specific area or channel, when the effect is applied.

| Grain |
| Blur |
| Color Correction 2 |
| Foreground Image |
| Color Correction 1 |
| Background Image |

FIGURE 11. Layer-based compositing principle.

Figure 11 shows the layer-based system of compositing images. The key concept of this system is that each layer has an effect on all the layers below it. Thus, even though Color Correction 1 layer effects only Background image, Color Correction 2 affects foreground element as well as background element, since it is below this layer.
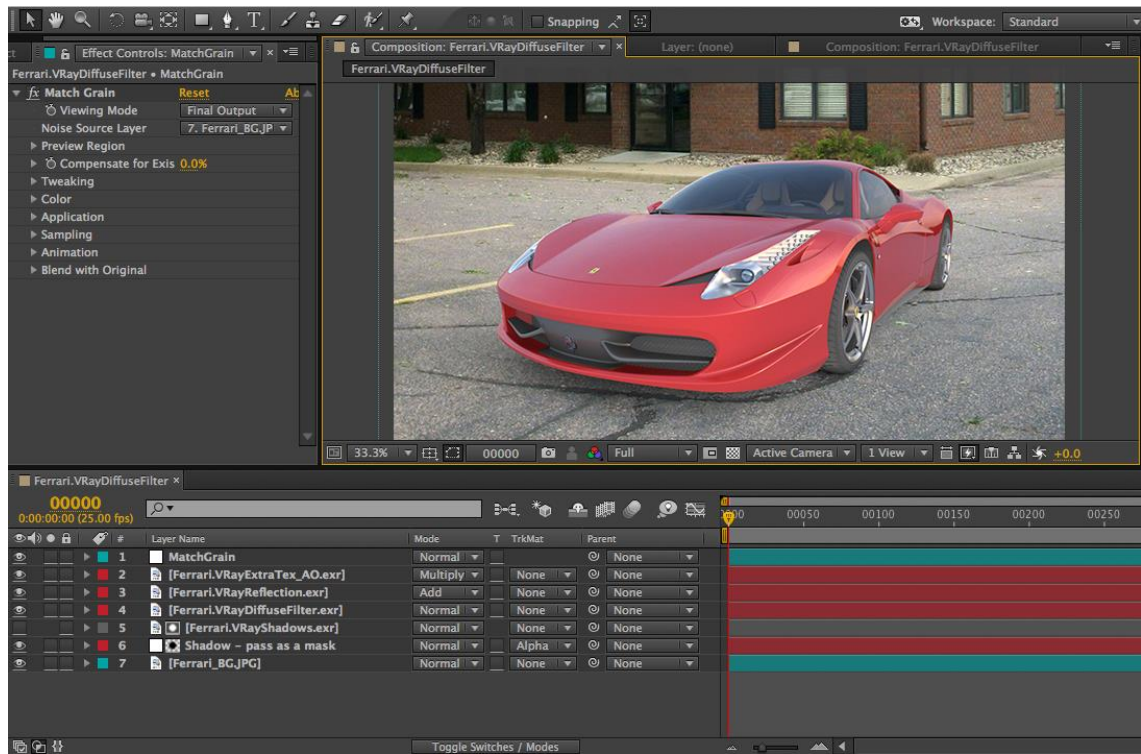
FIGURE 12. Compositing in Adobe After Effects (Ostasheva, A. 2015)

Specific effects can be applied to specific layers too. For instance, if a composer wants to color correct only foreground image with no alteration to any layer behind it, s/he has this opportunity. Blur effect can also be easily mask, such as Figure 9 shows the opportunity to mask Defocus effect in a node tree.

The industry standard of the node-based compositing is Nuke by The Foundry. It can be stated because majority of the industry leaders are using this exact software in their work-flow. Among those are Digital Domain, MPC (Moving Pictures Company), ILM (Industrial Light & Magic), Double Negative, Framestore, Method Studios and many others. Nuke (by The Foundry) was used for compositing in such movies as Harry Porter (all parts), The Trasformers (all parts), Hugo, The Real Steal, Alice in Wonderland, Rango, Sherlock Holmes, The War Horse, to name a few.

Interestingly, there would be even no need to compare these two systems if it would not be for Adobe After Effects. In fact, this is the only application that offers layer-based digital compositing possibilities. It is common to hear among compositors that After Effects should not be even considered as complete compositing software because the layer-based system cannot compete with the node-based one.

One of the projects that is most known by the public and uses After Effects for compositing purposes is TV series "The Walking Dead" (Sam Nicholson, Stargate Studio, Adobe at NAB 2014). It demonstrates that After Effects is powerful enough and provides all the tools for professional to accomplish a convincing level of realism in their composites.

FIGURE 13. A Still from "The Walking Dead" breakdown. (Stargate Studios, 2013)

The choice toward one or another system is justified by many aspects, such as the scale of production, the budget dedicated to software, complexity of shots, etc. It can not be said that any of those approaches fails to provide the necessary capacities for a composer. However, node-based software simplifies more complex operations (such as, for instance, light wrap or masking by channel), simplifies the representation of those processes. More and more producers of a new software tend to lean towards node-based system and prove it with their products – Figures 13, 14.
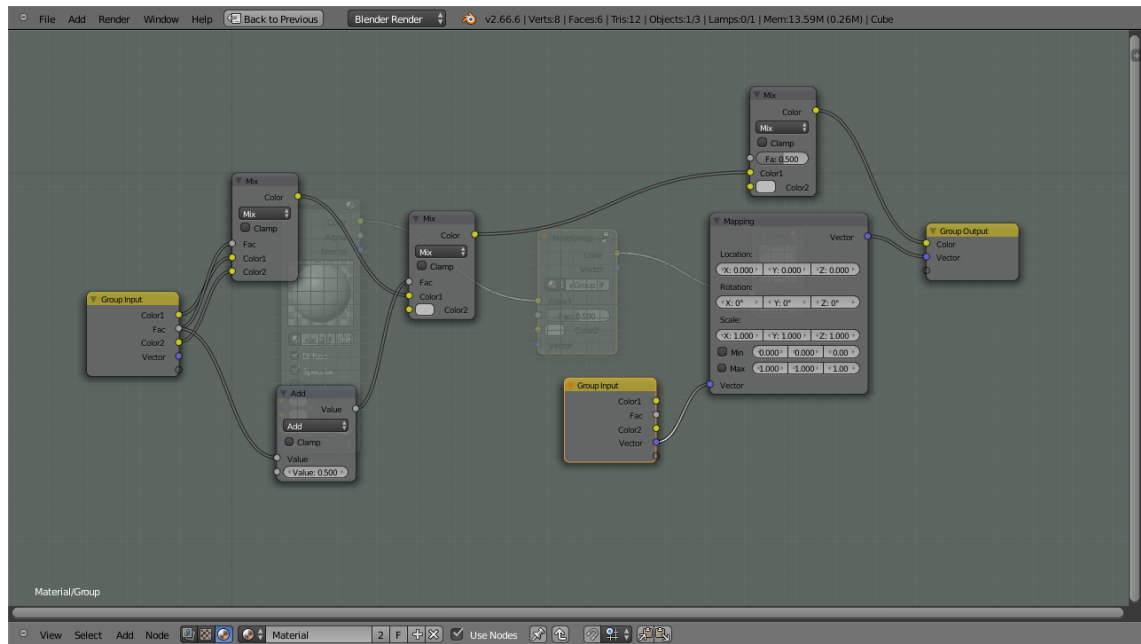
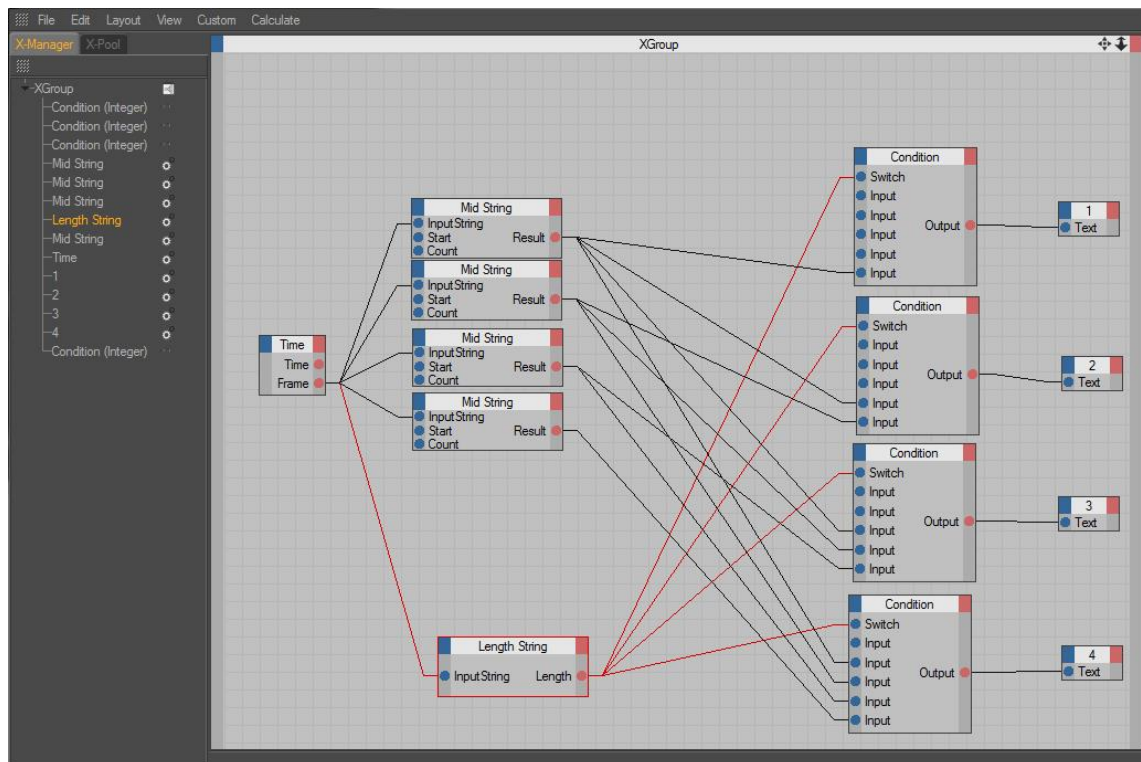FIGURE 13. Blender Node Editor (Blender 2.67 Official Manual, 2014)

FIGURE 14. Cinema 4D R16, Node-Based Xpresso Editor (Maxon's Official Manual, 2014)

2 MAJOR COMPOSITING OPERATIONS

There is a diverse range of different compositing operations which a compositor deals with, starting from a simple composite of two images up to keying and multi-pass compositing of 3D renders. This chapter is dedicated to those operations themselves, to their roles and purposes - the meaning behind them, rather than to specific actions which need to be taken in any certain software.

2.1 Image Compositing

Even combining two simple still images into one, maintaining the illusion that those images have been shot in the same place at the same time already is compositing and may require experience and skills to achieve realism. This process is widely used in motion pictures composites for limitless number of tasks: altering the scenery, adding or duplicating objects, replacing existing objects or parts of the image, etc.

In order to achieve high quality in a composite, several factors should be considered: the direction and intensity of lights/shadows, the color spectrum of lights, types of film grain or digital noise, quality of the selection.
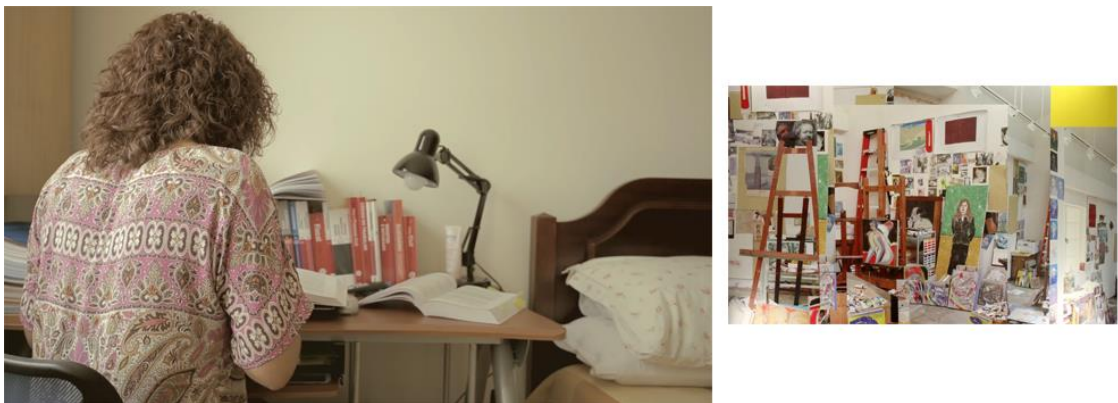

FIGURE 15. Two images that need to be combined.

A following example is meant to demonstrate the value of these factors. It can be assumed that a director decided to add a poster from a museum to the room of a character to underline her passion for studies, art and education – Figure 15. If those pictures would be

just placed over each other, there illusion on one whole would not be achieved – Figure 16.
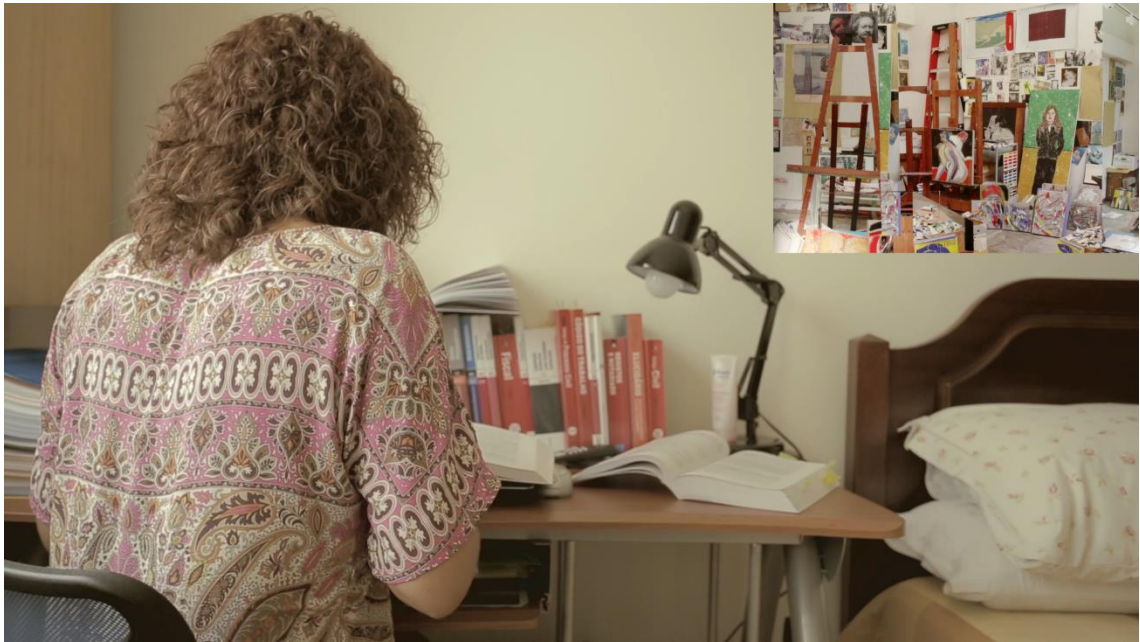

FIGURE 16. An image placed into another.

Even though these particular images already have a lot in common (temperature of light, color scheme), it is still obvious, that the poster does not belong to the room in reality. The reason for that is that the images differs in contrast, direction of light as well as sharpness. Interestingly, the parameters for those characteristics are already given to the compositor, in the original picture, in this case, in the picture of the young lady.

First thing that needs to be done is that black and white points need to be matched. That means that the darkest and the brightest points of two images should look as close as possible. Figure 17 takes a closer look at the comparison of the darkest and brightest areas of two images. It can be seen that the poster picture has deeper shadows (Figure 17A), whereas the white areas are rather close (Figure 17B).

FIGURE 17. Comparing black and white points of two images.

When matching the black and white points of two images, not only the brightness and contrast matter. Every pixel is built from combination of pixels from three channels: red, green and blue. Even when shadow and white areas are close in relation of brightness, the color spectrum of those areas may still be different. It is highly recommended to avoid this difference in color compound in any composite, because that ruins the illusion that two images have been shot at the same time in the same place and under the same lighting conditions.

After the essential color correction of the poster image, more can be done to improve the illusion even in this relatively simple example. What is important to remember is that there is no need to guess and invent solutions regarding how much to defocus the image, to denoise it or add noise to it; regarding the direction of light and whether any transformation should be done. In fact, all those answers are already in front of a compositing artist. The main image, plate, serves as a reference for all of those parameters. A closer look to the objects on the plate located close to the poster give us all this information.

The camera is focused on the lady and thus some objects placed further from the camera point of interest get slightly blurred. Such as the level of defocus of a lamp and a bed tells how much the poster should be defocused – Figure 18.
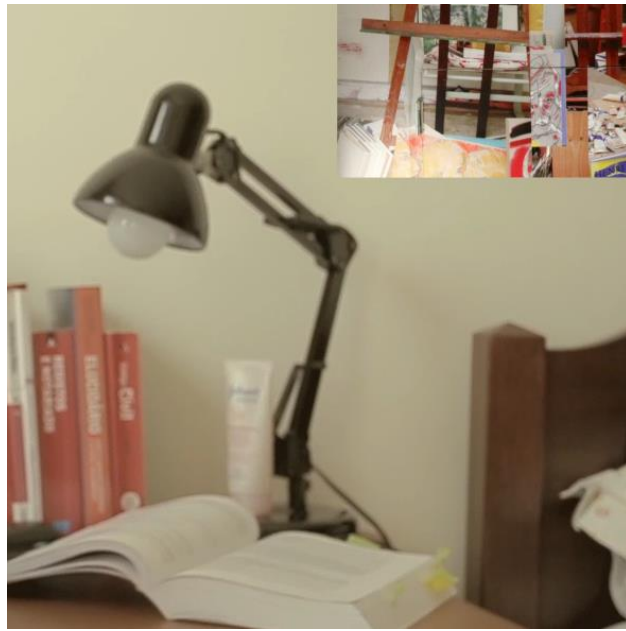
FIGURE 18. Studying the main image more closely.

The same principle is applied to all the other questions. For instance, vertical lines are rarely perfectly vertical in a shot. That is because of lens distortion, which may be subtle, but happens anyway. This should be used to increase the realism of a composite – vertical lines of a poster should be deformed in according to the verticals of a major shot. In Figure 18 this judgement can be done based on the vertical line of the bed.

Below (Figure 19) is the example of an integration of a poster. Darkest and brightest areas match, the general brightness of a poster relates to the general brightness of a room, the level of poster's defocus is based on the blurriness of the shot elements.

FIGURE 19. Final composite.

2.2   Multi-pass Compositing

The key concept behind multi-pass compositing is the opportunity to separate different areas, components and characteristics of an image (RGB colors, shadows, reflections, etc.) into different layers and channels. That gives a compositor a full control over the slightest details of an image as well as the ability to make dramatic changes without the time- and money-consuming process of going back to a 3D application and re-render materials again.

In order for a compositor to have information of one image in different layers (passes), a 3D artist should first render the image or image sequence specifying which digital information in particular should be present in the render. Depending on the 3D application or on a personal preference, different layers and channels can be stored either in separate files or in just one file. The file format that can include layered information and used by all the major 3D and compositing application is .exr² format.

Below is an image of a car made in 3D – Figure 20. This is the final look that has been achieved in a 3D application. This render pass is referred to as "beauty". Apart from this layer, however, 12 more layers have been rendered in addition to RGB information. They are presented in Figure 21. These particular passes have been chosen because they are most essential for making a composite with a full control over a scene. There are more passes and types of passes, for instance Lighting and Raw Lighting, UVs and others. They are not discussed in this particular example, since they serve rather advanced purposes or help when it comes to problematic troubleshooting. There is no golden rule on how many passes need to be rendered and how exactly a render must be broken into parts (Brinkmann, R. Art and Science… p.452). It is a decision making process that is based on a shot in question and on complications that may appear on any stage of a compositing work.

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² OpenEXR is a high dynamic range imaging file format developed by Industrial Light Magic (ILM). It is used by ILM on all motion pictures currently in production. The first movies to employ OpenEXR were "Harry Potter" and "The Sorcerers Stone", "Men in Black II", "Gangs of New York", and "Signs". Since then, OpenEXR has become ILM's main image file format (OpenEXR, ILM).

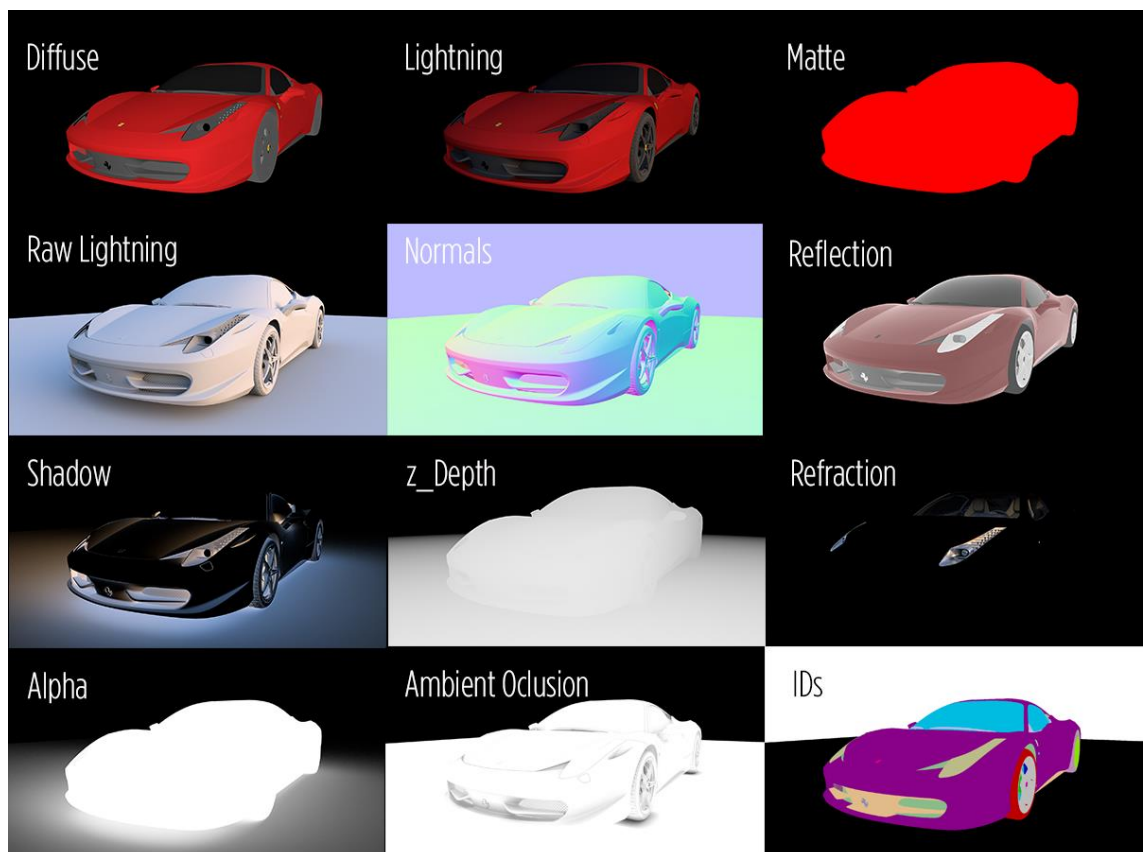FIGURE 20. 3D render. Beauty pass.

FIGURE 21. Additional passes (Ostasheva, A. 2015).

Each of the passes has its specific function and allows compositors to perform diverse tasks, such as:

Diffuse pass contains the main color information as well as illumination and allows to change color of an objects without affecting intensity of lights, reflections, shadows, etc.;

Shadow pass contains the shadow information and the capability to modify it separately allows to adjust the density and hue of the shadow without affecting other aspects of an image, such as luminosity of colors, reflections, etc;

The same principle is behind the **Reflection** pass. It holds the information about reflections and can be adjusted in according to the desirable look of a shot;

Ambient Occlusion pass includes information of shadows that closely positioned objects drop at each other, replicates natural behaviour of light and adds realism to the scene;

ZDepth pass allows a compositor to add and modify depth of field. The information of the pass is presented in the range between black and white colors, the brighter is the pixel, the closest is its location to the camera;

The pass called *IDs* contains information of different areas and elements of an image marked with different colors. That allows an artist to use any of those colors as a mask for any type of adjustments. Those **ID** passes have a significant importance when an artist is working with an image sequence and thus, **ID** pass saves time by preventing the need to make a selection of a moving object;

Normals pass allows a compositing artist to change the direction of light in a scene without coming back to a 3D application and avoiding a re-render.

Passes of a multi-pass render act as layers of an image. So that, each layer has up to 4 channels. For example, RGB layer contains information in at least 3 channels: red, green and blue one. In case there is alpha channel, it makes it 4 channels per layer. Nuke, for instance, has capability of processing 1023 channels per script[3] (Nuke User Guide, p.125).

Likewise, in *Normals* pass all 3 channels play an important role. The information in each of those red, green and blue channels is presented by black and white pixels (and the range

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[3] Script refers to Nuke's project file, to the node tree.

between them). Each of the channels has a different direction of light, so that, a compositor can modify this property, again, without affecting any other aspects of the scene, such as diffuse color of a car, intensity of lights, and intensity of shadows – Figure 22.
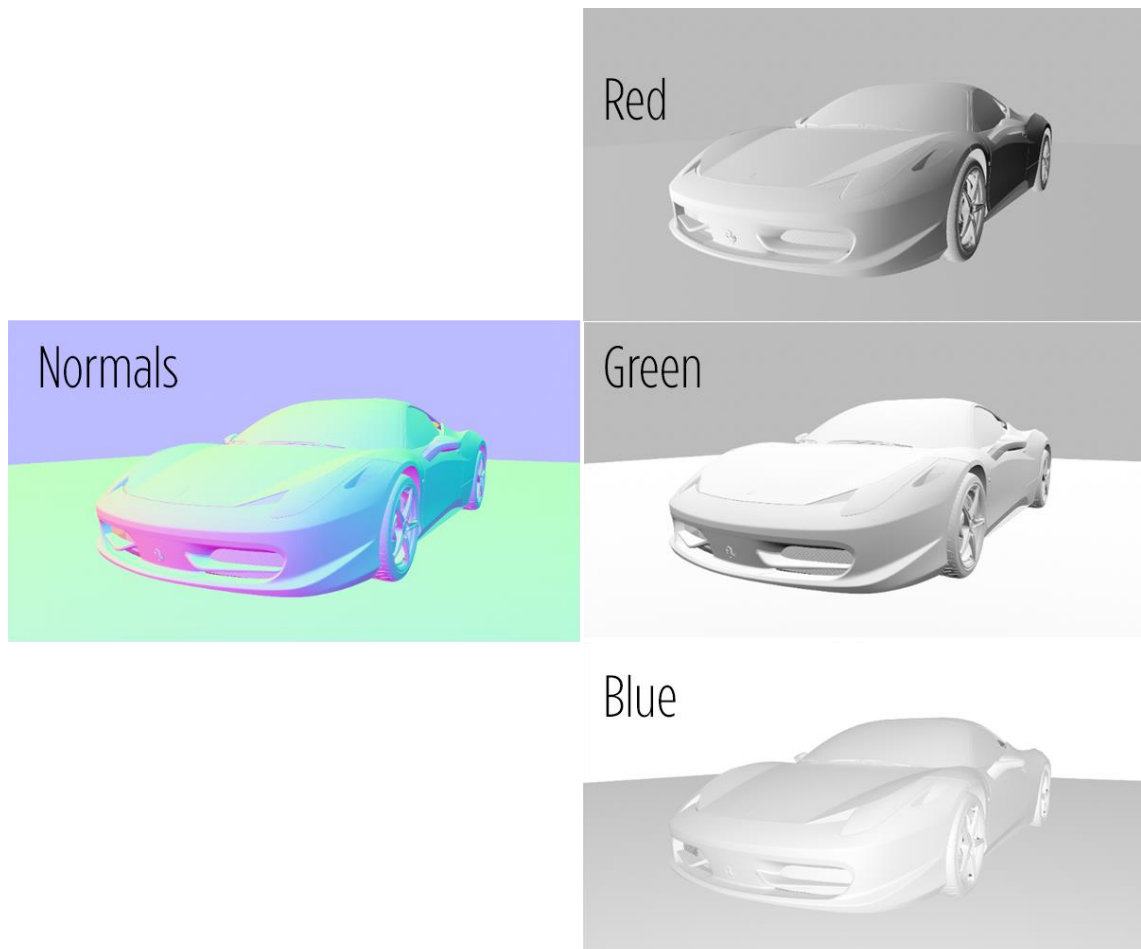
FIGURE 22. Normals pass and its channels (Ostasheva, A. 2015)

And the following example serves as a demonstration of diffuse pass capabilities. Figure 23 shows that color of a car can be changed drastically at the same time keeping other aspects of a scene untouched. The direction and intensity of lighting remains the same at all three images, the tires are as black as they were, the front lights' glass has taken no alterations either, only the hue of a car changes.
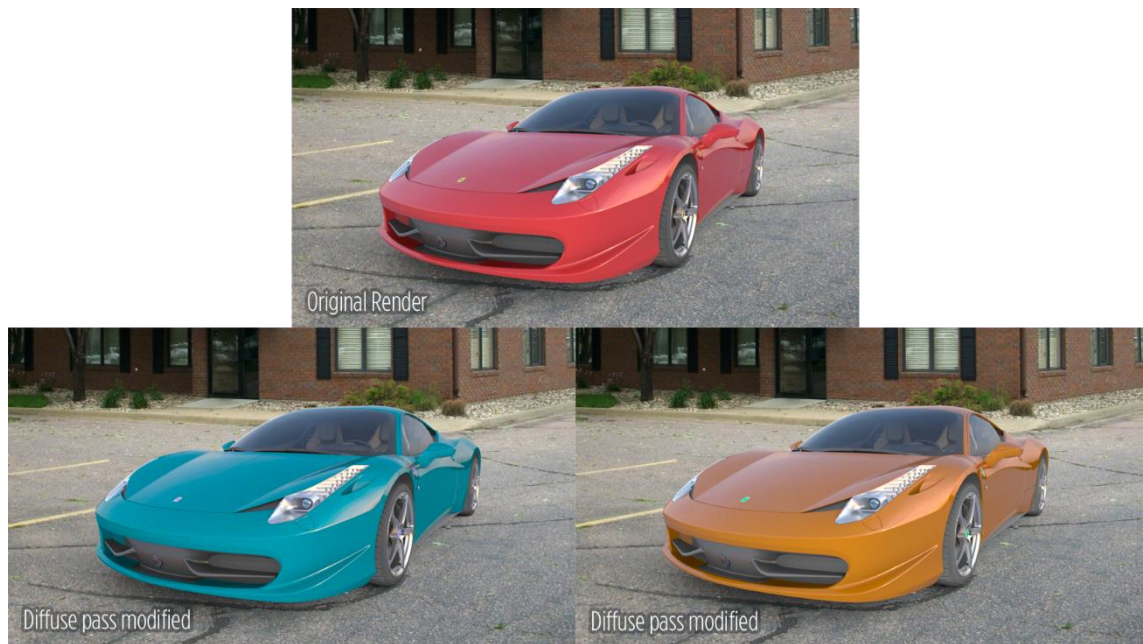
FIGURE 23A. Modifying Diffuse pass (Ostasheva, A. 2015)
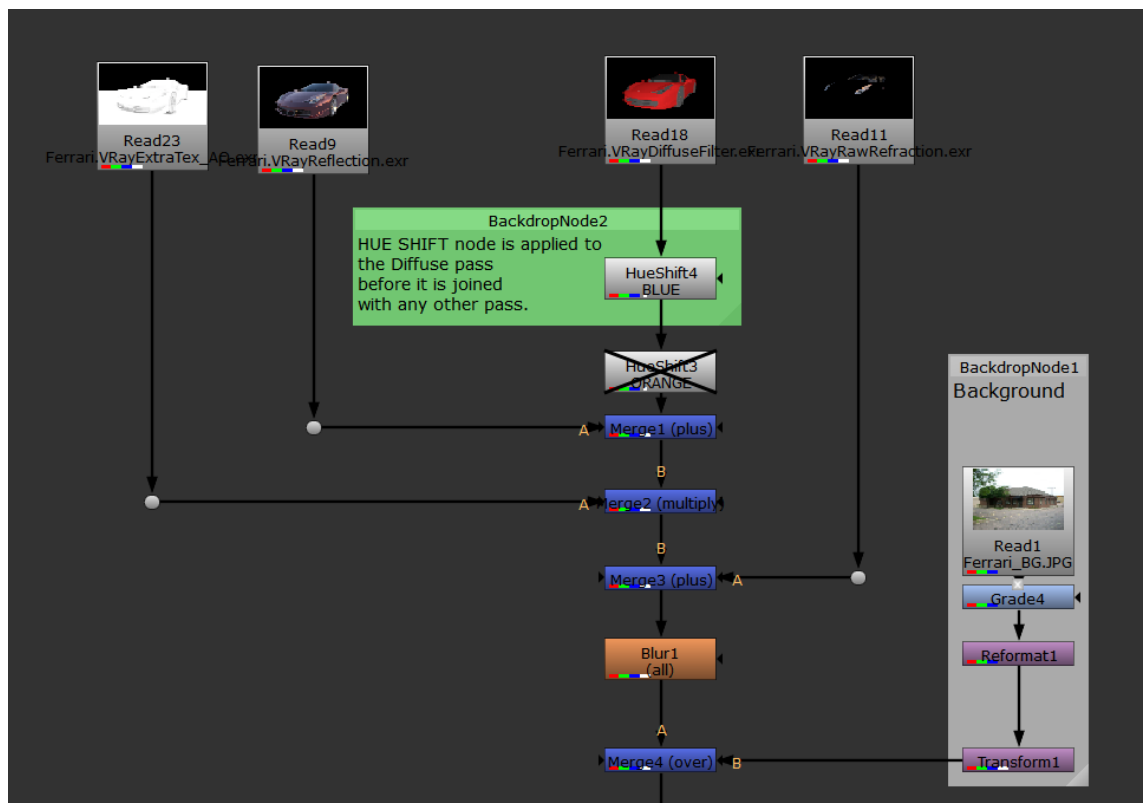
FIGURE 23B. Changing hue of the car in Nuke (Ostasheva, A. 2015)

The task to change the color of a car would be possible without having separate passes rendered, in theory. The result, however, would be of a lower quality – Figure 24. For this example the same Hue adjustment node was taken from the Figure 23. The node with exact same settings, except, it was applied not individually to a diffuse pass, but to

the whole car, to the "beauty" layer. In this case all the elements of a car got affected by that – windshield and front lights has changed dramatically. If working with a still image, those problematic areas could be easily masked, when it comes to working with image sequences, masking (rotoscoping) takes significantly more time and, for that reason, is better to be avoided.


FIGURE 24. Changing hue of a car as a whole object (Ostasheva, A. 2015)

Multi-pass compositing is used every time when any CG materials need to be composed. Every 3D application provides the opportunity to render a scene with additional passes and it is a responsibility of every compositing artist to be able to work with these materials, because through its technological advantage multi-pass compositing enlarges, above everything, artistic capabilities of a compositor.

2.3   Rotoscoping

Rotoscoping is the process of masking moving objects frame by frame. The purpose of roto work is to extract a certain area of a sequence, which will then serve as a mask. This task is often referred to as matte extraction.

Rotoscoping is a complicated process for several reasons. First of all, it takes a lot of time of routine work. Secondly, the roto work must be perfect, otherwise the jaggy edge and

unwished elements will ruin the illusion of a one whole, will reveal that elements or characters have been shot in another location. In addition, when working with footage or image sequences, a roto artist must deal with moving objects and consequently with motion blur. The complications that it brings up to a shot are shown on the figure below.

FIGURE 25. Example of Motion Blur.

Motion blur occurs due to a long exposure, which allows the same fast-moving object be seen in different places. When shooting moving pictures, the exposure may have appropriate setting for a regular show, but if there is an object that is moving too fast, it will appear blurred.

Figure 25 clearly shows the difference in edges. When doing roto an artist should mask out an object precisely by its edge. Motion blur destroys the edges, making it impossible to find a certain edge of an image. It creates areas of partial transparency and parts of an image merge with the background image (Fingers get so blurred, it is easy to see background through them). That is a grand complication for a roto artist. It is up to him/her to decide what will be defined as an edge and follow this principle throughout the whole shot.

If a roto artist faces a task to extract a person from the shot, to create a mask for this person, s/he uses several masks for one character. The more complex is an object to mask out, the more masks will be used. This is because it is often easier to move position of several masks than change one big mask itself. A roto artist first analyses the footage and all the parts of a target objects. Then, based on the movement of all the elements, makes

a decision how to split these objects. A good illustration of this division as well as outstanding roto work can be found in a demo reel of Nathaniel Caauwe, who has done rotoscoping for such movies as "Captain America", "Harry Potter", "Avengers" and many others.

FIGURE 26. A still from the movie "Captain America".

(Roto work by Caauwe, N. 2012)

Apart from its technical nature, rotoscoping can also be used for more artistic purposes. A few of the most famous examples of that are the movies "A Scanner Darkly" and "Waking Life", which used the masking technique to completely repaint the image.

FIGURE 27. A still from the movie "A Scanner Darkly", 2006.

FIGURE 28. A still from the movie "Waking Life", 2001.

It is worth mentioning that rotoscoping has its limitations and is not able to accept any challenge, to handle any selection. Motion blur as well as the finest details such as hair and fur cannot be captured by splines' selection, they create semi-transparent areas that may be practically impossible to select by masking. In addition, it is worth to remember that masking a sequence of images is not the same as masking one image. Even when the masks are reasonably good for every single frame of a sequence, the edges may be placed in slightly different places and those tiniest changes will distract the viewer when looking at the sequence in motion. Because of the fact that rotoscoping may not be a solution for every situation, other tools for extracting mattes were created. One of them is keying.

2.4 Keying

Keying, or chroma keying, is the process of separating a foreground element from a background of a consistent solid color. The color used for the background is usually blue or green. That is a consequence of the processes behind the technology itself. What is happening inside a computer is that a user indicates to the system pixels of what hue diapason must be eliminated. The computer defines a given color range and eliminates those pixels. Since in majority of cases it is people who are shot against the background that needs to be removed in the future, the color of the background needs to be as far from human skin tones as possible. If a chroma screen would be orange, red or, for example, pink, the

computer would not make a difference between a foreground and background elements, it would eliminate all red-containing pixels, consequently, making a process of extraction of a character meaningless.

The short movie "Four Heads Are Better than One", made in 1898, mentioned earlier (Figure 3 p. 7), has a lot in common with a keying technique. What Georges Méliès did was, basically, keying, but based not on the color, but on luminance. He managed to eliminate all the dark pixels from the film when compositing it with another film. Nowadays, this technology has advanced and every compositing software offers not only chroma key tools, but luma key tools as well.

In other words, keying is the digital technology that allows to separate elements faster and easier, which is, once again, caused by the necessity to combine several images from different sources together.

The process of keying happens not only inside of a compositing application, but may also happen in real time. The best example of this is a weather forecast, when the audience sees a reporter placed over a map. The process of keying happens in real time. The computer "knows" that green or blue pixels in the image should not be displayed and it keeps up doing it even in real time with moving elements.

FIGURE 29. John Sauder, CBC weather reporter on air. (Lee, D. 2014)

The technique is widely used in the modern moving pictures production and it is a duty of a compositor to extract objects. It helps to recreate situations which could be practically impossible to film without keying technology. For instance, people falling from a roof, getting on top of a moving car in the middle of a speed highway, landing on Mars, etc. Hence, according to Jeff White, Industrial Light & Magic Visual Effects Supervisor (The Avengers Featurette, Joss Whedon, 2012) the movie "The Avengers", while the story takes place in New York, all the movie was shot in New Mexico, expect an aerial shoot of the New York city – Figure 30.

In a production of a smaller scale chroma key technology is often used as well. The green keying technique allows not only to replace the background but also substitute parts of an image without the need to do the frame by frame masking – Figure 31.

FIGURE 30. A still from the movie "The Avengers". On the left – final composite, on the right – original green screen shot (Industrial Light & Magic, 2012)
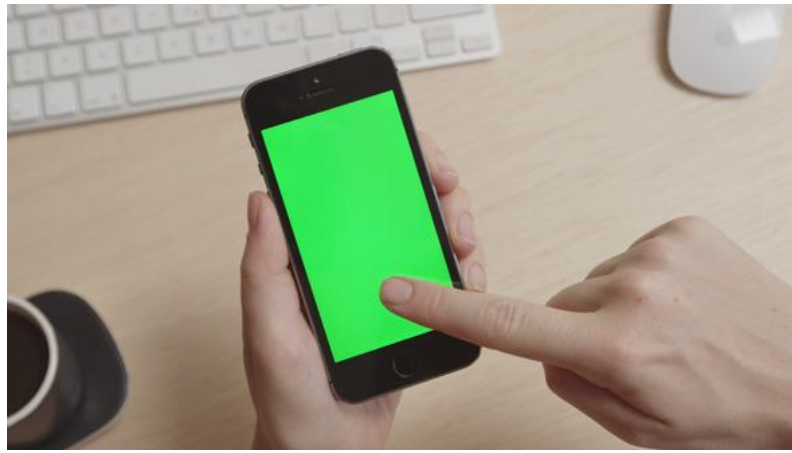
FIGURE 31. Example of the usage of chroma key
(Girl using a smartphone…videohive.net)

2.5   Rig and wire removal

In order to provide neccessary safety for actors or replicate a complex movement of objects of a scene, wires are used during the shooting. When the live action plates are done, they go to a visual effects department where compositors remove all the safety elements out of the shot.

The process of replacing unwanted pixels seamlessly is rather challenging. Because of that, post-production companies try to shoot plates that need this kind of treatment over blue/green screen, so that the wire merely needs to be eliminated and background is added later. If, however, a plate was shot without chroma key, a compositor or roto artist must deal with the seamless background restoration. This task may be very complex and time consuming.

The image below illustrates one of the cases of wire and rig removal. The actor is jumping from the roof. Not only do we see a wire that provides an opportunity for the jump but also the camera slides on the same wire to shoot a close-up of the hero during the time of the jump.

FIGURE 32. A still from the movie "The Bourne Legacy"
(Wire and rig removal by "L256", 2012)

What complicates the task are detailed backgrounds, movement in the background, change of luminosity or complex 3D camera movement. This particular example can be considered relatively simple because the background, the sky, has no sharp small details, no change in color or luminosity as well as the camera has 2D linear movement.

There are several methods, basic approaches, when it comes to wire removal. One solution is to find a frame in a sequence which is covered by the destructive elements as little as possible, and later place this frame over problematic areas. In relation to the example above this method could be used to restore the building in the left bottom corner.

Judging by the movement of a hero and positioning of the camera it can be assumed that in the following frames the rig will cover the building. That would literally mean that in a certain frame range there will be no pixels to form an image of the building. In this case, a compositor takes those pixels from other frames of a shot, when the rig was not overlapping with the building, and places them above those s/he needs to remove.

If this approach is impossible to use, an artist had to paint out the wire frame by frame. In theory the task seems easier than it is. The reason for this is movement. Even when 24 cleaned up frames look perfect independently, when in movement, the problematic area may look "boiling". Not only should a wire be removed from each frame, but it should be done with exatly the same pattern. That becomes even more complicated if the elements of the background are moving or change color or lightning.

It is important to remember that working with footage compositing artists work not only with colors of an image, but also with grain. The grain is an inconstant element – its pattern changes every frame. Thus it should be treated carefully and this pattern should be restored as well. In most cases, however, compositors and clean up artists denoise footage first, perform cleaning operations and finally, replicating the original type of grain from a live action plate, apply it above the clean composite. That helps to increase the illusion that everything was shot without any wires and rigs.

Since the camera movement in a shot perplexes the clean up, another method is meant to eliminate a movement from the plate first, clean up a plate and then retrieve the movement. This can be achived by stabilizing a shot and later inverting the stabilization, which bring the initial movement of the camera back to the shot. Figure 33 breaks down the process from a node-based perspective.
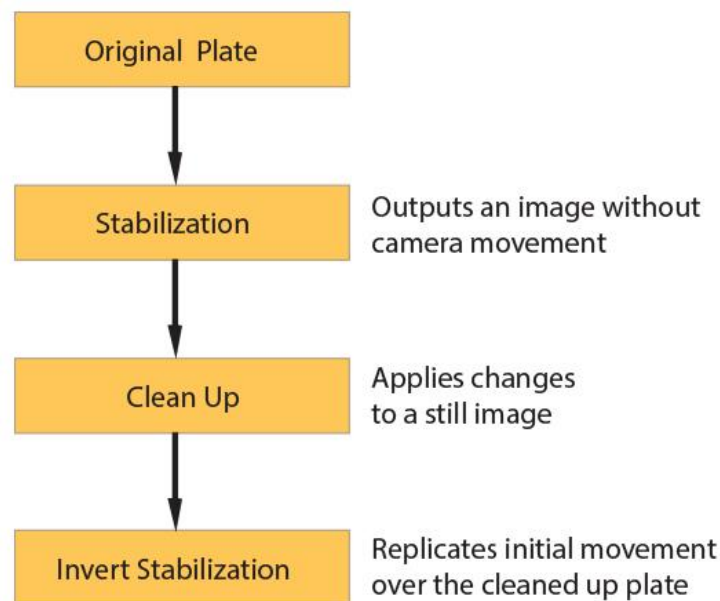

FIGURE 33. Schematic visualization of the inverted stabilization (Ostasheva, A. 2015).

2.6 Clean Plates

The process of creating clean plates resembles the rig and wire removal process, except, more significant parts of a live action plate need to be modified. The reason for that may be extraneous objects in a scene, replacing objects, the change of a director's plans or simply the absence of project files.

The methods to approach this kind of task are the same as explained in the chapter above – frame by frame paint out, making patches, stabilizing a shot for a clean-up. Below, there is an example of a necessity to create a clean plate when replacing an object. The client wanted to replace the aeroplane in the shot to demonstrate a new aircraft design. The original project has been done by one company, the replacement was assigned to another.

Figure 34 shows that it is not enough just to place a new object over the old one. The old plane will still be seen and ruin the illusion. So it needs to be removed. Again, it is recommended to keep in mind that these examples are about image sequences, not still images. There is camera movement and the movement of objects present. Thus, those techniques that may be useful for a still image are inapplicable for a clean-up artist. The sky needs to be replicated not in a static form, but in relation with a camera move.

In this shot, the second method has been used – the footage was stabilized (excluding the moving plane), one frame was repainted and then applied to the shot with a reverse stabilization. Grain was applied above all.

FIGURE 34. Aeroplane replacement (Ostasheva, A. 2012)

The following example relates to extraneous objects in a scene. The idea behind the shot was that the car, because of its manoeuvrability, manages to escape from a falling rock. When the rock falls down it crashes over the ground, which produces a lot of dust and dirt. In order to increase the interaction of dust elements (which are part of a future CG

rock) with a car (which is a live action plate), the VFX supervisor used a mechanical cannon to shot the dust up in the air when the car was passing by, so that the dust could interact with a car and blur out a viewer's understanding of where CG comes to change up the live footage.

FIGURE 35. Clean up (Ostasheva, A. 2012)

2.7   Tracking

Tracking, which may also be referred to as motion tracking or video tracking, is a process of trailing an object or a group of objects in a footage. The purpose is to track an element

of a scene and add any other external elements, such as CG elements or paint out patches, over this footage considering the original movement. That helps to integrate those elements into the footage, where they behave with the exact relation to the camera as the objects in a scene.

There are several more specific types of tracking and each of them is widely used for a wide number of purposes. More precisely they will be discussed below. Despite the abundance of tracking methods (one point tracking, planar tracking, 3D tracking) the principle behind the technology remains the same.
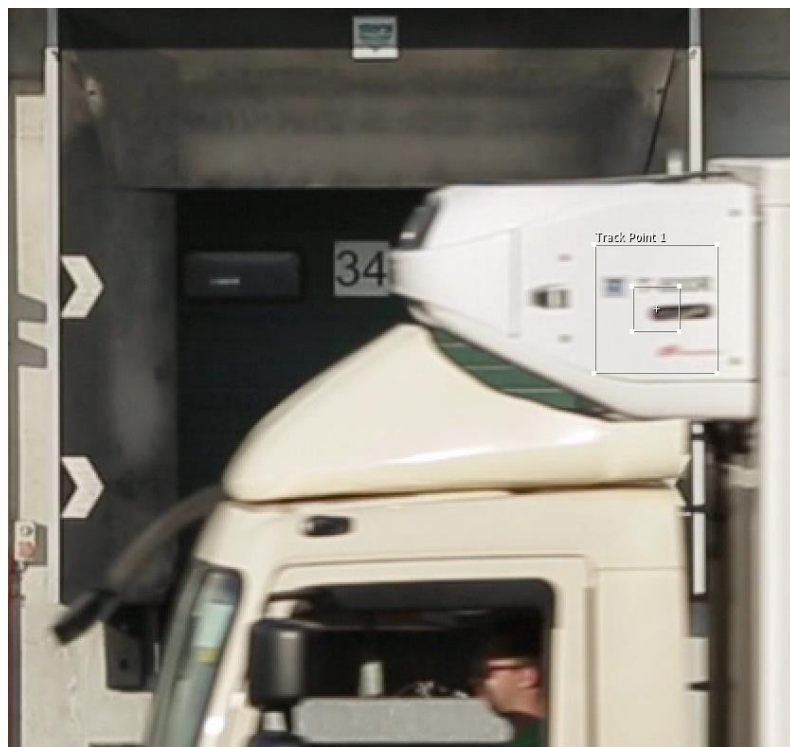

FIGURE 36. Tracking a point.

The image above shows a tracker interface from Adobe After Effects (software is irrelevant because tracking interfaces in different applications use the same principle and look very much alike). The task is to track an object in order to get an exact information of every change in its position (rotation, if there are more than 1 point) value. In order for the application to do that, the area, object or group of pixels with the highest contrast possible should be selected. That allows the computer to "see" the tracker target more clearly. The difference between pixels can be based on contrast (luminosity) or color (hue). The more difference between a tracking point and its surrounding the easier it is for a computer to keep track of it.

The smaller square indicates which area of pixels should be tracked and should surround this group of pixels relatively tight. The bigger square indicate a presumable area in which the tracking pixels may travel. The bigger this square is, the more time and processing resources computer will need to calculate the movement.

The image above is a still frame from a short sequence showing a truck passing by the camera. It is a common scenario in a small post-production companies to buy stock footage online and then adapt it for a client. That saves a lot of production expenses as well as time. In an imaginable situation the task of a compositor could be, for example, to place a logo of a client company to this track. In order to make a logo "sit" right on top of the truck and move exactly like it would be glued to the car, the software needs to calculate the movement of the truck and apply this movement to the logo. In other words, make tracking.

Figure 36 shows a placement of a tracker in the area of a highest contrast – black sticker over white car. During the process of tracking, the software finds these pixels in a frame and makes a key frame for a positing value at every frame of the footage. This data can be later applied to another layer – the logo – which will result in an illusion that the logo was "sitting" on the car in the first place.

2.7.1 One point tracker

The example above already gave some information about tracking footage with one point. However, the application of this technique is unlimited. It can be used as for technical purposes, like the example above, for clean up purposes, as well as for artistic purposes.

If a compositor would have a task to erase all the details from the top of the car, s/he could paint everything out on one frame and afterwards simply tracked in into the footage. In many situations it would save a lot of time in comparison with painting out every frame.

FIGURE 37. Stills from a sequence of a flying airplane (Ostasheva, A. 2014)

Figure 37 shows how knowing the tracking technology can be used for adding artistic elements to a shot. In this particular case the airplane was tracked so that the animation imitating the vigilance interface was added. The changing position values of the airplane were applied to the animation, making an illusion that the animation is interacting with footage.

One point tracking opens up a wide range of technical and creative possibilities for a composer and some creative concepts may even be based entirely on this technique. One of them is the opening title sequence for an American TV series "Person of Interest" (Nolan, J. 2011).

FIGURE 38. "Person of Interest", a still from the opening sequence (Nolan, J. 2011)

2.7.2 Planar tracker

The planar tracking technology was introduced inside a specialized tracking software called Mocha by Imagineer Systems in 2001 (What is Planar Tracking? An intro to mocha by Wright, S. 2010). Mocha is compatible with the majority of other applications for Motion Graphics and Video Editing.

Planar tracking takes advantages of flat services, objects resembling a plane – a pattern of pixels moving relatively one to another. The examples of planes in the surrounding world are most commonly screens, walls, signs, etc.

As an alternative to planar tracking for a screen, for example, can be tracked with four separate trackers. The Mocha technology's advantage versus four separate points of a track solves a track at once, saving a compositor's time.
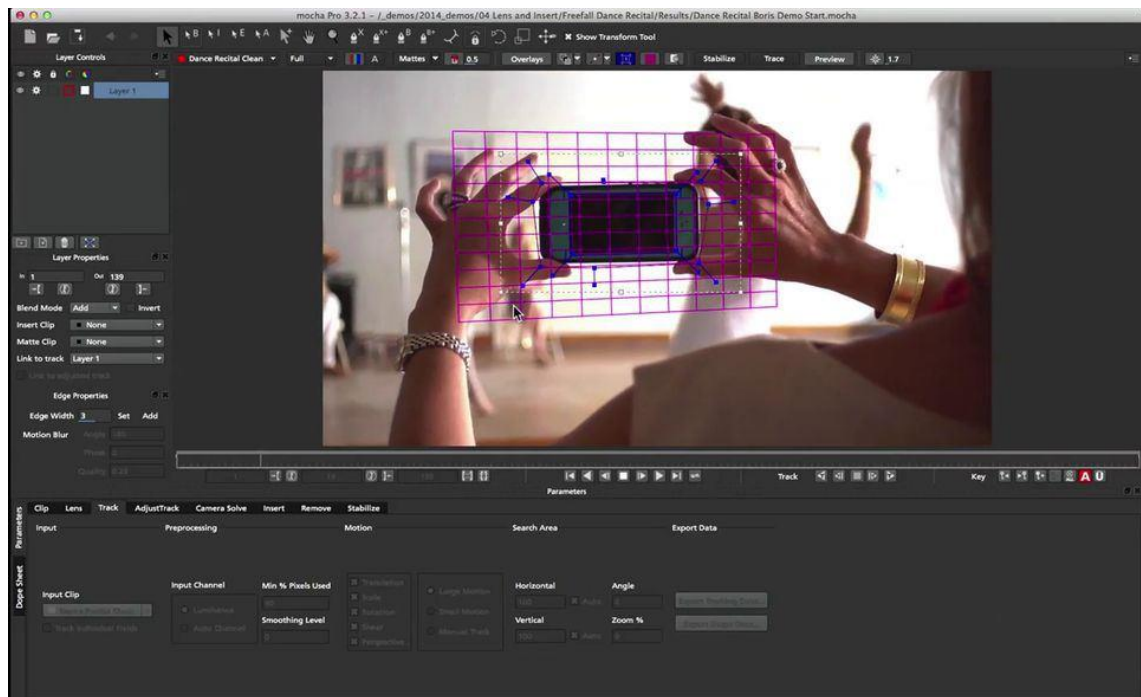
FIGURE 39. Planar Tracker interface inside Mocha (Imagineer Systems, 2014)

2.7.3 3D camera tracking

3D Camera tracking or match moving allows digital artists to insert objects, for instance CG elements, into live-action footage plates that have a moving camera. Based on the movement of different objects and features relatively to each other and to the camera, the software analyses those movements and creates a virtual camera that moves and rotates in three-dimensional space. Afterwards, this camera data can be applied to a 3D element to replicate the same relation between objects of a scene and a camera. When a CG element is later combined with a live-action footage, it seems that CG object was shot at the same time with the plate.

Despite the fact that a camera solving (calculation of a movement and creation of a virtual camera) is done by a compositing application, the success of 3D camera tracking depends drastically on the skills of compositor. This is because an artist sets several important parameters, often selects the key point for a tracker and masks out areas of the image that disturb the tracker.

Figure 40 demonstrates how this process of calculating the movement of the camera looks inside Adobe After Effects. Colorful crosses illustrate positioning of the points which the

software is tracking. Their size is relative to their distance from camera – the smaller is a tracking mark the further away is the object or a surface from the camera. This principle of finding a spot of a highest contrast is identical to one point tracking technology. The difference is that in match moving the relation between those dots matter.

FIGURE 40. 3D Camera Tracker interface inside Adobe After Effects CC 2014.

In this particular shot the camera is moving from left to right and closer to the people. If a task of a compositor was, for instance, to integrate a 3D model of a laptop so that it would look like a laptop is laying on the table, s/he would need to track the shot and as a result get a virtual camera created and, afterwards, just place a laptop on that table. There would be no need to animate neither position, rotation nor scale of a model. Not only would the process of animating be very time-consuming but also, in many cases with this technique it would be practically impossible to reach a level of realism which 3D camera tracking provides.

2.8   Lens Effects

The knowledge of the processes that happen in a camera when shooting are crucial for a digital compositor who tries to imitate that materials completely produced via computer have been shot by a real camera. A viewer does not have to possess any specialized

knowledge to distinguish what has been shot by a camera and what is entirely CG. Eventually, it comes to perception. There is no need to study visual effects to be able to spot a fabrication. For that reason, it is a part of a compositor's responsibilities to understand those processes and be able to replicate them in order to achieve the highest level of realism in their composites.

This chapter breaks down the most significant and most commonly used effects of this replication. It also shows how detailed compositing artists are in their goal to fake reality.

2.8.1 Lens Distortion

Lens Distortion is presented on an image by bended lines. Those lines that we know by definition, are vertical, such as building walls, road signs, etc. get curved in an image. This is cause by lenses of a camera and consequentely the type of distortion depends on the type of lenses.

There are three types of lens distortion barrel, pincushion and moustache distortions. Barrel distortion is associated with wide-angle lenses, when lenses try to receive more surrounding information in comparison with tele lenses, for instance, wich is typically associated with pincushion distortion. The moustache distortion, also known as complex distortion, is the combination of two previous types. It starts with a barrel distortion in the center of a frame and gradually transforms into pincushion distortion closer to edges of a frame.

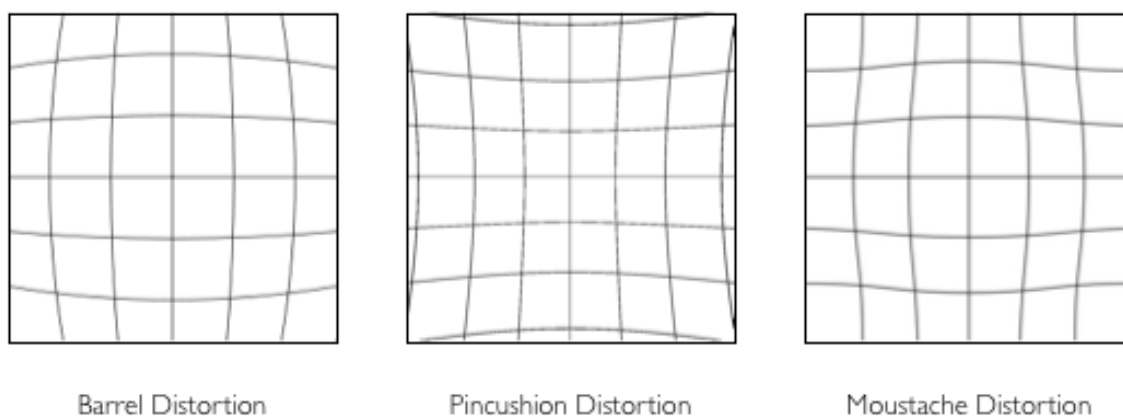Barrel Distortion   Pincushion Distortion   Moustache Distortion

FIGURE 41. Types of lens distortion (Kamps, H.J. 2014)

It is common in photography that lens distortion occurs too strong. The majority of image editing software offers tools for correcting lens distortion, for example Spherize effects in Adobe Photoshop. Any compositing software offers those tools as well (CC Lens in Adobe After Effects, Lens Distortion node in Nuke, etc). In compositing and VFX production, however, those tools are used to create the distortion, to replicate the behavior of a realistic camera lens and eventually to increase the realism of CG materials.

2.8.2 Spherical Aberration

As the definition states itself, spherical aberration is a type of optical abnormality, oddity. This artifact may occur in any optical device, such as mirror, glasses, etc, and certainly inside camera lens.

There are several types of lenses that photographers and cinematographers use in their cameras, figure below. In all the lens types it can be clearly seen that a lens deforms and its curveness and thickness in the area of edges is never equal in those characteristics to the center of a lens. That is the key reason for an aberration to appear.
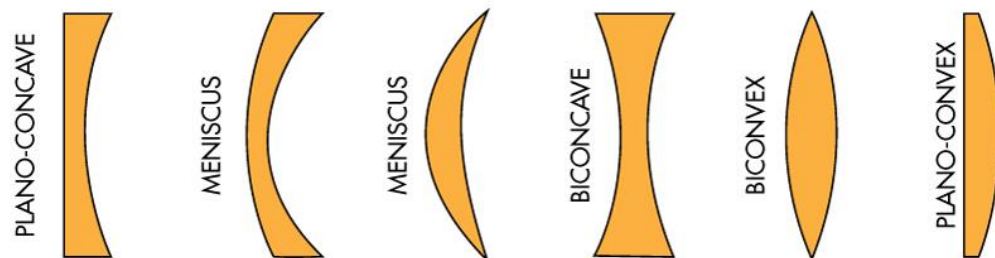
FIGURE 42. Main lens types (Ostasheva, A. 2015).

Hense, the spherical aberration is an optical effect that happens when beams of light go through the lens. Since the curvature and thickness of a lens is not equal in the center compared to the edges, light beams refract differently. As a results, rays don't come to the same focus point and consequently an image gets blurred.
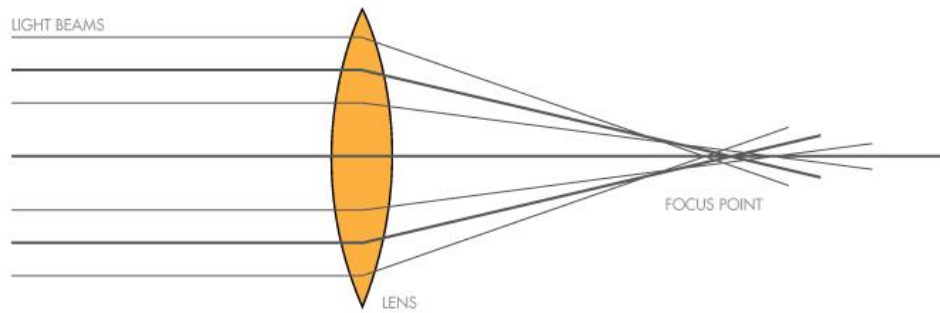
FIGURE 43. The nature of spherical aberration (Ostasheva, A. 2015)

Not only does the difference in rays refraction affect the focus of an image. Another common type of peculiarity of an image is chromatic aberration.

2.8.3 Chromatic Aberraction

The previous figure depicted the refraction of beams of light. During this process of re-fraction, the light beam itself gets split into colors. Chromatic aberration is also known as "color fringing" or "purple fringing". Despite its name chromatic aberration is an optical process of rays' refraction that makes it impossible to focus different wavelengths of color into one point – Figure 44.
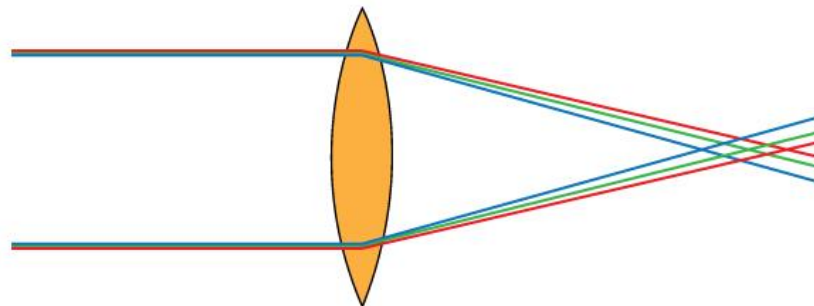

FIGURE 44. Chromatic aberration (Ostasheva, A. 2015).

In photography and cinematography strong chromatic aberration is present almost in every picture, shot, etc. However, it quickly becomes a problem when it becomes too present - it destroys the true color of objects and decreases the quality of an image. The figure below demonstrate a significant spread of color wavelengths. It was taken with

Canon 60D with a feature "Chromatic Aberration Correction" off, lens EF-S 18-135mm f3.5-5.6 IS STM f3.5 ISO 100.

FIGURE 45. Chromatic Aberration.

Interestingly, chromatic aberration has become fashionable in Motion Graphics and VFX production. Not only do compositors introduce a small amount of this optical phenomenon, but also consciously apply it to an extreme degree. An attentive viewer of motion graphics has definitely seen the majority of such works or/and will definitely see many more. When it comes to moving pictures, this extreme aberration of color waves is refered to as "channels' split effect" and the level of aberration is often animated, thus creating an illusion that an images splits into its components.
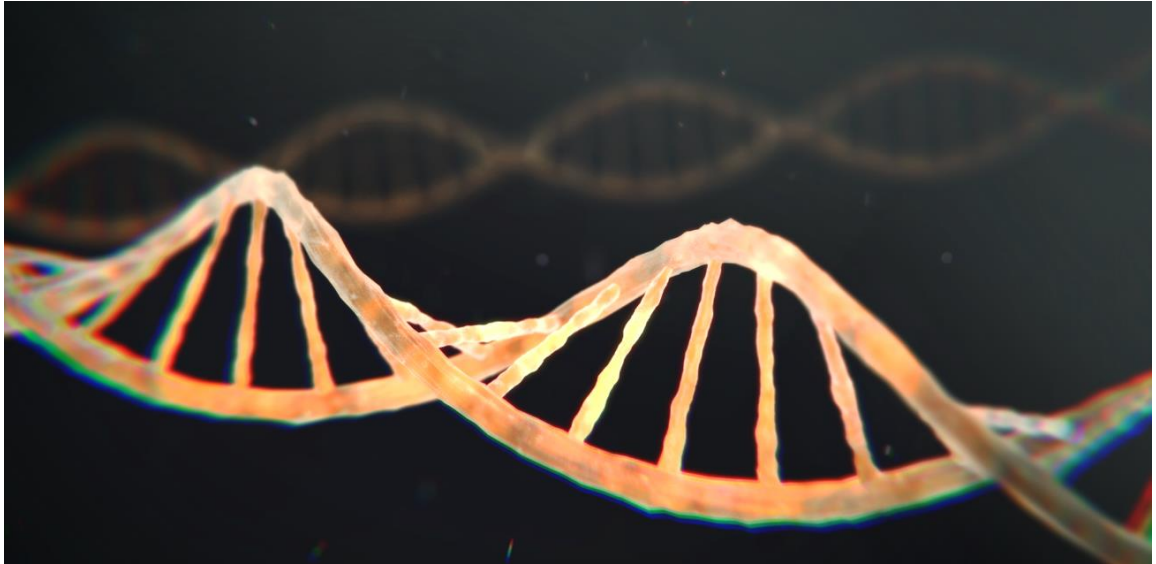
FIGURE 46. Chromatic Aberration in Motion Graphics (Ostasheva, A. 2014)

Reality is that lenses are not perfect and they distort images even slightly, still, enough for a viewer to feel the difference. For a compositor it is essential to be aware of those inperfections of lenses, so that s/he may use this knowledge to her/his advantage.

2.8.4 Depth of Field

The term Depth of Field, or shortly DOF, refers to a range of distances, in which objects of the image appear to be sharp – Figure 47. In the world of photography, for example, cases of having every element of a scene completely sharp are rather rare. This is because that never happens in real life either. The human eye focuses on certain object(s), immediately defocusing other elements in the view range. Not only do compositors and digital artists replicate DOF in order to amplify the illusion that CG elements have been shot through real lens, but also to imitate the natural behavior of a human eye.

Parameters of DOF may vary significantly since DOF depends entirely on the setting of a camera, such as aperture, focusing distance and lens length. That's why there is absolutely no defocus on elements that have been created computery generated. However, all the applications that allow a user to create a virtual camera (After Effects, Nuke, Cinema 4D, Blender, Shake, Flame, and others), provide as well the opportunity to modify such settings as activation of DOF and adjustments of aperture and focus distance.
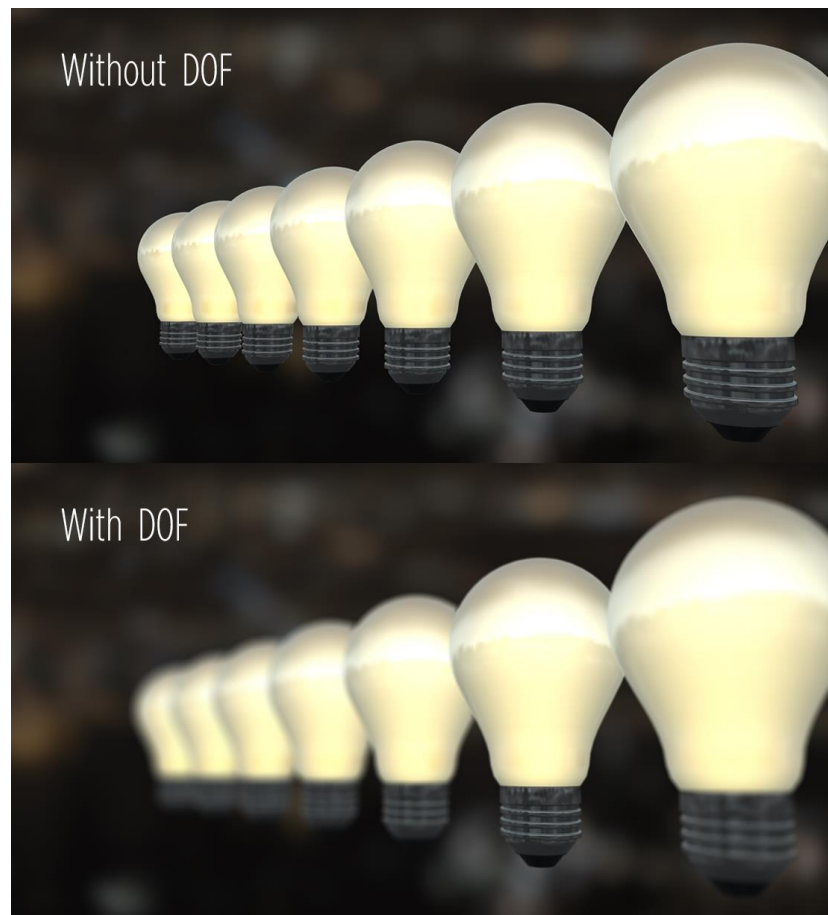
FIGURE 47. Depth of field demonstration (Ostasheva, A. 2015)

According to Ron Brinkmann, the author of Art and Science of Digital Compositing, the majority of believable composites include a certain level of defocus in a scene (Art and science…, p.31). As mentioned in chapter 3.1, Multi-pass Compositing, depth of field is created with the help of ZDepth pass. A 3D artist creates a virtual camera in a scene, which may even be animated, and sets up the setting defining depth of field. After that, ZDepth pass is rendered – Figure 48. Information in this pass is always presented by pixels in the range between black and white pixels, ensuring the smooth transition from defocused areas to sharp ones. This pass may be, however, modified. For instance, increasing the contrast of the black and white gradient of ZDepth pass, would decrease the smoothness of this transition.

Depth of field and the process of its replication during the compositing stage has a significant importance for a scene or a shot, because it helps to achieve the most desirable outcome – realism. Adding DOF to the image is relatively fast, except that it increases render time, since computer needs to execute more calculations. Figure 49 demonstrates

the composite of a car that was presented in Chapter 3.1. with and without DOF and serves as an example of the improvement that DOF can bring to the shot.

FIGURE 48. zDepth pass demonstration. The further away elements are from the camera, the darker are pixels in zDepth pass (Ostasheva, A. 2015)

FIGURE 49. Adding DOF to the car composite (Ostasheva, A. 2015)

2.8.5 Lens Flares

Nowadays, lens flares are an integral part of post-production. It is a rare thing these days to find a movie or a music video without a replication of a lens flare. Originally, lens flares get born inside of a camera. It is a result of light being reflected, scattered in the lenses of a camera. When a beam of light reflects from one lens and hits another this is what causes a flare to appear on the film or a sensor. In post-production, adding flares meant not only to replicate the feeling that all the elements inside this shot (which may be fully CG elements) have been shot with a camera, but also for artistic purposes.

It is highly recommended for compositors to understand why lens flares happen in real world. Without this understanding, it is easy to make an unrealistic choice, which can be even if not seen but rather felt by the audience. Since a lens flare is a beam of light bouncing between lenses it cannot happen without a direct light source, for instance.

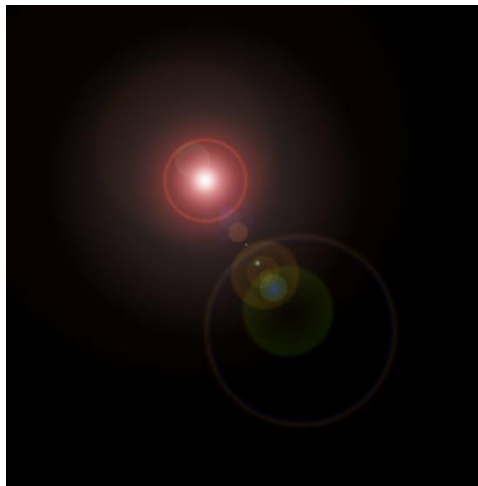Diverse compositing and Motion Graphics software offer some tools to replicate flares inside a program.

FIGURE 50. A default Lens Flare effect in Adobe After Effects CC 2014.

FIGURE 51. Applying lens flares to enhance an image ("Supernova" by Loyale, 2010)

To sum up, lens flares are a powerful tool to seamlessly merge two different images into one. However, the reason for a lens flare to appear are important to remember in order not to overdo the effect for a realism expense.

2.8.6 Vignette

Vignette is another type of aberration that is happening when light is entering the camera. There are two primary types of vignetting: **natural** and **optical**. In the first case, because of the shape of lenses and a hood of lenses, a frame receives less light in the area of edges as a result of being reflected from a hood. Replicating vignette is one more way to reproduce the illusion that the scene was shot by a camera rather than being assembled on computer.
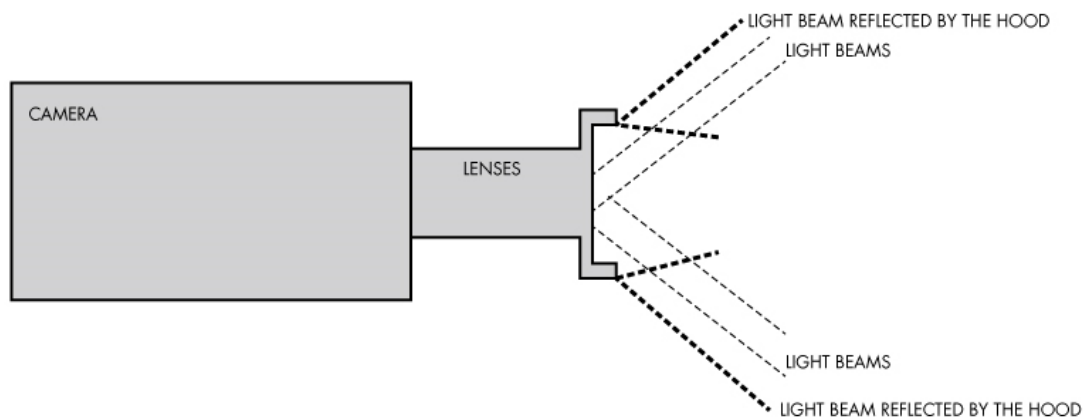

FIGURE 52. Light beams got reflected from the lens's hood resolving in a vignette
(Ostasheva, A. 2015).

In the case of optical vignette, the images gets distorted around the edges of a frame because of the shape of lenses (Figure 42, p.48), which change its shape and thickness at the edges, preventing a sensor from receiving the equal amount of light for every part of a frame.

FIGURE 53. Illustration of optical vignette (Bowker, D. 2013)

Not only does vignette imitate the behavior of realistic lenses but also helps to lead attention of a viewer to a logical center of a composite. It guides the viewer's eyes to the center of an image. Below there is an example of the same image with and without a vignette, so that its impact can be seen more clearly.

FIGURE 54. Comparing two images without and with natural vignette.

Even though this example is rather extreme, it indicates very well how the accent of lighting can emphasize a certain part of an image, pointing at the "hero" of an image and guide the view of an audience.

The technique of creating a vignette when making compositing of a shot is very commonly used in the VFX production. Firstly, because it mimics the natural behavior of the human eye, since our vision loses sharpness and brightness around edges of our view range. And, secondly, it may help a compositor to guide the attention of a viewer in a desired direction. However, it is important not to go overdo this effect. Vignetting, as well as a majority of other effects, works best when it is subtle, when a viewer can *feel* it, not necessary *see* it.

2.8.7 Grain and Digital Noise

Grain is an optical effect which is presented by random granularity on the image. Grain takes its origin from the certain levels of a photographics film, more specifically, small particles of metallic silver. Those particles result as granularity after being exposed to light. Since grain gets born on the film inside the camera, originally this is an analog process. Compositors add grain to their work in a digital invironment, in order to increase the illusion that the image shown has been shot with a camera.

With the appearance of digital cameras and when sensors came to replace the film, a new type of grain started being produced by the sensors – digital noise. These two types of granularity are different in their appearences as well as they don't have equally important impact on the image.

Film grain pattern is completely random and changes with each frame, because small silver metallic particles are located randomly on the layer of the film. On the contrary, digital noise may have a visible pattern, often result in vertical or horizontal lines across the image. Figures 55 and 56 are the examples of both demonstrating this distinction.

If the goal of a compositing artists is to achive a cinematic look and to increase realism, then s/he adds grain to the image. Normally, compositors tend to avoid having digital noise. On the subconscious level an image that has digital noise is percieved by a viewer as a low-quality image, rather than a cinematic picture (Smith, L. Digital Tutors, Film Grain and Digital Noise...).

FIGURE 55. Example of a real 8mm film grain with an organic random granularity.
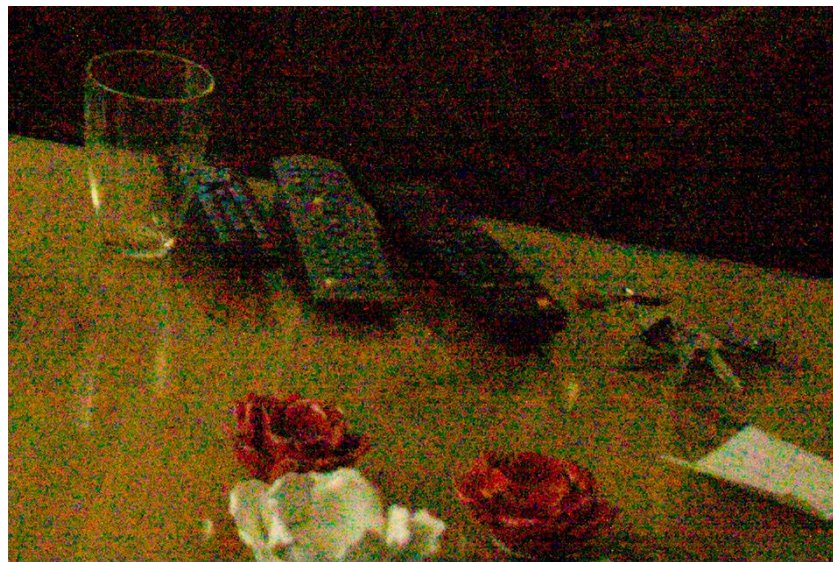(Image by HolyGrain.com)

FIGURE 56. Example of digital noise. The pattern presented in colored lines can be
seen.

For that reason, compositors try to eliminate digital noise and overlay film grain above. This process is often referred to as FGO – film grain overlay – and that gave a reason for the whole industry of film grain to appear. For instance, HolyGrain Company with a slogan "Shot digital, watch film" (holygrain.com).

3   SHOWCASE

In this chapter, a composite of one shot will be overviewed, the major steps discussed and illustrated. The compositing application in question is Nuke by the Foundry.

Figure 57 shows a still frame of a final composite (the link to the video: https://youtu.be/v_xUs-uzz8s). The task was to integrate a CG eagle into a footage that has a camera move. In order to integrate the eagle into the footage, I needed to make 3D camera tracking, animate the eagle, apply a solved camera to this animation (so that the background plate's and the eagle's movement would be in the same relation to the camera). The next step was the integration of CG element by color correction, light wrapping and, finally, replication of lens effects – lens distortion and chromatic aberration. All those steps are demonstrated below in more detail.

FIGURE 57. Final composite (Ostasheva, A. 2015)

Figure 58 demonstrates how the composite looked like after just placing the 3D eagle into the footage. It can clearly be seen that the lighting does not match – the white areas on the eagle's face have a lot of blues, whereas the lighting of the background plate is warm, with the domination of yellow tones in the bright areas.

FIGURE 58. Placing the CG eagle over the background plate with no integration (Ostasheva, A. 2015)

FIGURE 59. Node graph for the Figure 58 (Ostasheva, A. 2015)

Figure 59 shows what has been done inside of Nuke at this point. First of all, the eagle was built from major passes – diffuse, specular, reflection, shadow – so that I would have the opportunity to make adjustments for each of this property without affecting others. The background plate is located on the left side of the script. After 3D camera tracking, Nuke generated a virtual camera, which data was applied to the eagle, so that it would look like all the elements of the scene have been shot at the same time.

In the next step – Figure 60 – I matched the black and white points, so that the luminosity and color spectrum of shadows and highlights would look similar – Grade node 8. Grade 9 node is an animated gamma correction. Judging by the scenery of the background plate, I assumed, that when the eagle approaches the camera, the trees that are outside the frame would cast shadow on it. As a result, gamma value decreases when the eagle approaches the trees. The result of those steps is presented in Figure 61.

FIGURE 61. Color correcting the eagle (Ostasheva, A. 2015)

It is worth to remember that in the real world there hardly are any objects that would have a mathematically sharp edge. It is practically impossible. For that reason it is recommended to add a blur to CG elements between 0.4-2px depending on the element.

In the following step I created a light wrap effect, trying to imitate the real-life behaviour of light, which wraps around the edges of objects, bounces from them, etc. Literally, Nuke allows to do it by taking the pixels from the background plate covered by the

eagle, allows a user to blur them as much a needed and, afterwards, those pixels are applied to the eagle, creating the illusion that the light from the background scene affects the eagle. The node graph for this operation is presented below.
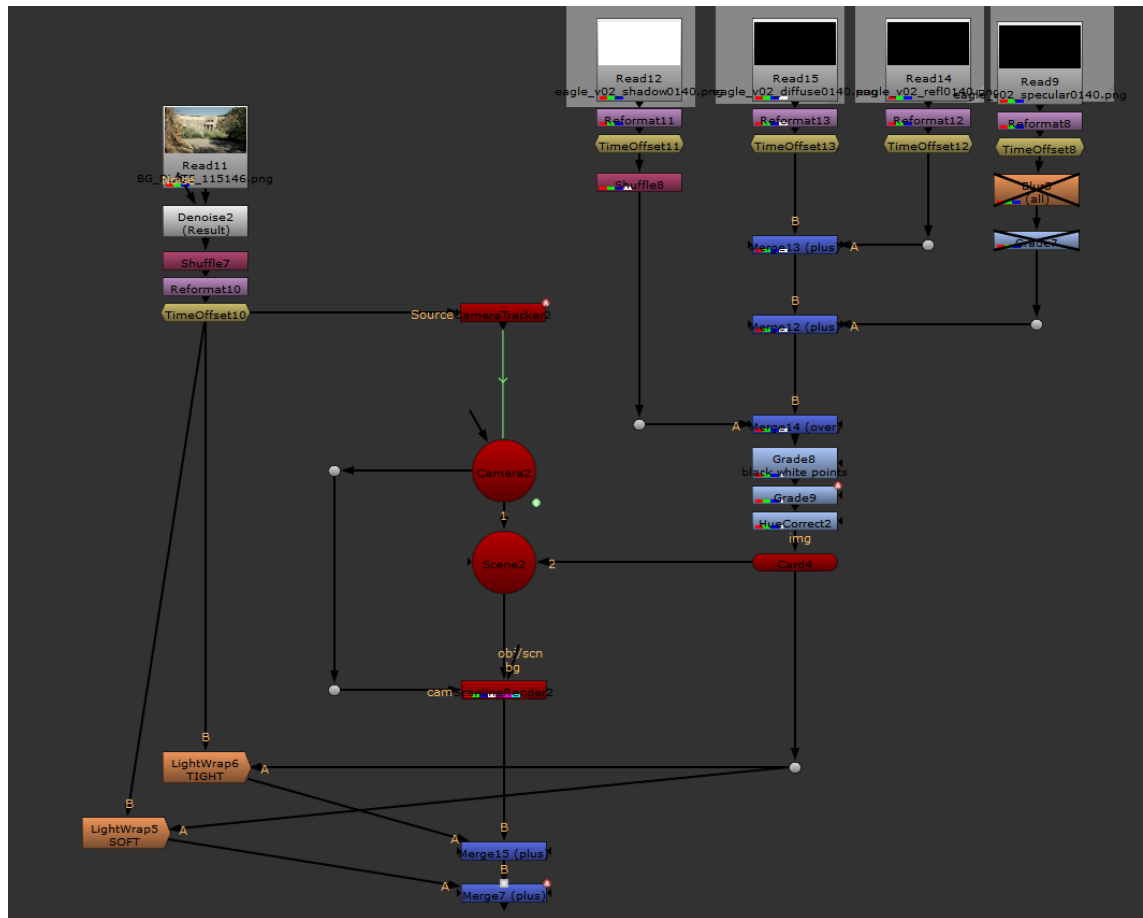

FIGURE 62. Light Wrap operation in Nuke (Ostasheva, A. 2015)

It is a matter of my personal preference to split light wrap into two parts – a tight edge and the soft light. Learned from more experiences composers on practice, this method proved that this way the artist gets more control over the light surrounding the CG element. The soft light wrap effect is animated. I increased its intensity when the eagle is far away from the camera, in order to increase the illusion of the atmosphere. The illustration of this effects is presented by Figure 63.

FIGURE 63. Light Wrap Effect (Ostasheva, A. 2015)

The next step to improve the illusion of eagle's presence in this environment was to add shadow that it would cast being in those lighting conditions. The most effective way to do that would be to rebuild a surface of the environment presented on the background plate in a 3D application (possibly, with a low level of details), create a light source with the same direction as the light in the footage and render out a pass with this drop shadow information for the compositing artist. In this particular case, however, I replicated the shadow in Nuke, since I didn't succeed with the task in the 3D application. The result of this shadow is present in Figure 64. What I lost was the precise positioning and deformation of the shadow when falling on the rock.

After that I moved to the lens effects and, first of all, added a little lens distortion to the shot. So that the footage and the CG element have the same deformation on the edges of the frame, replicating the illusion that both have been shot via the same lens.

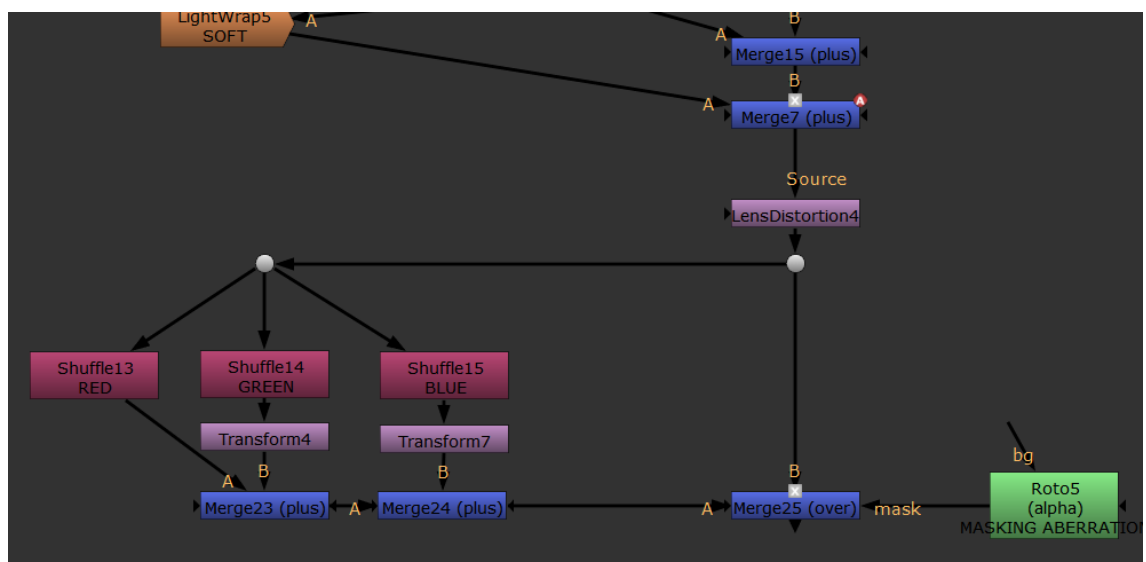FIGURE 64. Adding drop shadow (Ostasheva, A. 2015)

FIGURE 65. Chromatic aberration node graph (Ostasheva, A. 2015)

Apart from a lens distortion I added chromatic aberration as well. I split the main node tree into three channels – red, green and blue – distorted two of them and joint back together by adding pixels information to each other – Figure 65. In order to apply this effect only at the edges of the frame, since this is how chromatic aberration happens in real life (see p. 49), I placed the effect over the original composite and masked it with a roto node.

As a final step, I added a soft vignette to guide the viewer's attention more towards the eagle, to emphasize that it is the "hero" of the shot and added grain. I did not match the

grain with the background plate, because I've denoised the plate before importing in Nuke, so that I could just add the same grain to both elements – Figure 66.
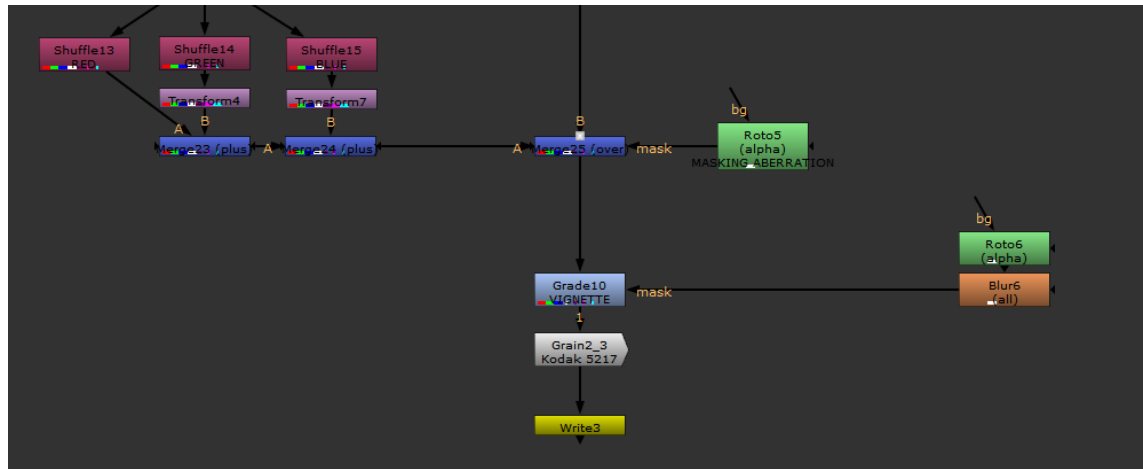

FIGURE 66. Adding vignette and grain. (Ostasheva, A. 2015)

As a criticism to this composite I would like to mention that the perfect illusion depends not only on a compositor's work. All the elements of the shot should be perfect and complement each other. As it can be seen, the animation of the eagle is not perfect – the overall timing and movements of the eagle, in particular, could be improved. Unfortunately I don't work neither with animation of 3D characters nor with rigging. So, in this part I had a lot of complications and just tried to do my best.

4   CONCLUSION

Digital Compositing has come to the industry of VFX production to stay. Not only does it save computer powers, time and money to companies and freelance artists, it raises the limits of what ideas are possible to implement in a tight schedule. Being a part of the pipeline, Digital Compositing supplements 3D applications, as well as offers compelling solutions for 2D imagery challenges.

From a point of view of an artist, Digital compositing is a fascinating form of art. It is an astonishing fusion of technical and artistic skills. Replacing backgrounds, eliminating objects from a shot, integrating fantastic CG characters into realistic worlds, creating fantasy environments and whole new worlds for a viewer's entertaining – those are the challenges that a digital compositor deals with.

Digital Compositing is a powerful and highly demanded craft. The need to create a believable illusion on the screen is an integral part of modern imagery production. Constantly evolving specialized software provides more and more tools and possibilities for digital artists to create those illusions, making the most unexpected ideas come true, at least on the screen. However, all the possibilities of this digital art can not be brought to a conclusion. As long as the expectations of the audience grow, as far as its fantasies go, Digital Compositing will follow. Evolving, surprising and inspiring the audience.

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