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Methods for producing stereoscopic imagery

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METHODS FOR PRODUCING STEREOSCOPIC IMAGERY

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master in Fine Arts
Digital Production Arts

by
Matias Volonte
August 2012

Accepted by:
Dr. Timothy Davis, Committee Chair
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Dr. Donald House

ABSTRACT

This paper describes methodologies for creating computer graphics stereoscopic imagery. This thesis details the positive and negative aspects for producing and post-producing stereoscopic imagery using different stereoscopic tools provided by *Autodesk Maya* and *The Foundry Nuke*. Also, in order to increase efficiency and decrease production time, Python tools were developed both for Maya and Nuke. Finally, the methodology proposed in this paper is fully functional and can be adopted by any production.

DEDICATION

I dedicate this thesis to Catalina. She really helped, supported and dealt with my workaholic schedule. Also, I would like to thank my family, mamá, papá, gabi, Cruz, Pedro, Paz, viki and javi, for supporting me and being there any time I needed them.

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TABLE OF CONTENTS

	Page
TITLE PAGE	i
ABSTRACT	ii
DEDICATION	iii
ACKNOWLEDGMENTS	iv
LIST OF FIGURES	vi
 CHAPTER	
I. INTRODUCION	1
II. BACKGROUND	4
2.1 Monoscopic depth cues	4
2.1.2 Perspective lines	5
2.1.3 Relative size	6
2.1.4 Texture gradient	6
2.1.5 Occlusion	7
2.1.6 Atmospheric medium	7
2.1.7 Motion parallax	8
2.2 3D Steresocopic depth cues	9
2.2.1 Interocular separation	9
2.2.2 Retinal disparities	9
2.2.3 Vergence, convergence and divergence	10
2.2.4 Accommodation	10

2.2.5	Positive, negative and zero parallax.....	11
2.2.6	Retinal rivalry	11
2.2.7	Anaglyph filters	12
III.	IMPLEMENTATION.....	15
3.1	Introducing methods for production of stereoscopic imagery ..	15
3.2	Software selection.....	17
3.2.1	Autodesk Maya 2012	17
3.2.2	Autodesk Maya camera.....	17
3.2.3	Maya stereo camera system	18
3.2.4	Compositing package.....	22
3.2.5	The Foundry Nuke	23
3.3	Stereo production work for <i>LiFe</i> and <i>Spider Fight</i>	24
3.3.1	<i>LiFe</i>	25
3.3.2	<i>LiFe</i> : shot one	26
3.3.3	<i>LiFe</i> : shot two	27
3.3.4	<i>LiFe</i> : shot three	28
3.3.5	<i>LiFe</i> : shot four	29
3.4	<i>Spider Fight</i>	30
IV.	RESULTS	40
4.1	<i>LiFe</i> final output	40
4.2	<i>Spider Fight</i> final output.....	42

V. CONCLUSION AND FUTURE WORK	46
REFERENCES	47

LIST OF FIGURES

2.1	Perspective lines.....	5
2.2	Path walk texture.....	6
2.3	Cubes occlusion	7
2.4	Forest fog	8
2.5	Parallax map.....	11
2.6	Safe stereo map	12
2.7	<i>LiFe</i> in stereo	13
2.8	Anaglyph filters	14
3.1	Stereo device	16
3.2	General viewer	16
3.3	Camera clipping planes.....	18
3.4	Single camera rig	19
3.5	Right stereo camera properties.....	19
3.6	Stereo attributes	20
3.7	Film offset.....	21
3.8	Converged camera alignment	21
3.9	Parallel cameras alignment	22
3.10	Nuke interface	24
3.11	Node operations	24
3.12	<i>LiFe</i> : shot sequence	25

3.13	<i>LiFe</i> : shot one	27
3.14	<i>LiFe</i> : shot two	28
3.15	<i>LiFe</i> shot three	29
3.16	<i>LiFe</i> : shot four	30
3.17	Top view camera.....	31
3.18	Shot one field of view	32
3.19	Shot two field of view	32
3.20	Shot three field of view.....	32
3.21	Panoramic view.....	33
3.22	Multi stereo camera system	35
3.23	Maya render layers.....	36
3.24	<i>Spider Fight</i> Nuke script.....	37
3.25	Stereo interaxial separation editing in Nuke.....	38
3.26	Nuke 3D system.....	39
4.1	Final render of <i>LiFe</i> : shot one.....	40
4.2	final render of <i>LiFe</i> : shot two	41
4.3	final render of <i>LiFe</i> : shot three	41
4.4	final render of <i>LiFe</i> : shot four.....	42
4.5	Final stereo for <i>Spider Fight</i> : part one.....	43
4.6	Final stereo for <i>Spider Fight</i> : part two.....	43
4.7	Final stereo for <i>Spider Fight</i> : part three	44

4.8	Stereo panel interface, version 0.5	44
4.9	Stereo panel interface, version 0.9	45

CHAPTER 1

INTRODUCTION

In June 2010, *Toy Story 3* was released in the United States. This film was projected in two formats: 2D and 3D. By the end of the year, a report of ticket sales showed the following: the 2D version sold 21 million tickets with revenue of \$165 million, representing the 40% of the total gross of the movie, while the 3D version sold 31 million tickets with revenue of \$248 million, representing 60% of the total gross. Similar effects occurred with other movie releases such as *Alice in Wonderland*, *How to Train Your Dragon*, *Clash of the Titans* and *The Last Airbender* [Tenn11]. These examples highlight the interesting effect of stereoscopic 3D on viewer choice and therefore, on box office revenue.

Hollywood is aware of this trend, as evidenced by DreamWorks CEO Jeffrey Katzenberg's announcement in 2007 that all future projects will be released in 3D format [Main09]. George Lucas also announced that he will be re-releasing all of the *Star Wars* films in 3D [Luc10]. These examples confirm that stereoscopic 3D truly represents the present and future of filmmaking.

Stereoscopic 3D technology is not new. Single-image stereoscopic viewers were developed in the 18th century, but stereoscopy did not experience widespread popularity until the 1950's when it was included in feature film productions. Many factors converged to elevate stereoscopic films to popularity, but the main factor was economics. The film industry was losing its audience, as evidenced by the fact that movie attendance

in the U.S. dropped nearly half, from 82 million to 46 million, between 1946 and 1952 [Lipt82].

In November 1952, however, a stereoscopic film, *Bwana Devil*, grossed \$100,000 in its first week [Lipt1982]. The years of 1952 to 1955 are considered the “Golden Era” for stereoscopic films; however, they were discontinued due to deficiencies in 3D technology. Producing stereoscopic footage and providing correct projection were complicated and inefficient. These issues resulted in an unsatisfactory experience for the spectator; therefore, 3D lost its appeal.

Today, film studios are once again producing movies in stereoscopic format for two reasons. The first is the economic factor detailed previously. The second is that the improvements in stereoscopic productions are finally able to meet viewers’ expectations and enhance their experiences.

Producing a film containing computer graphics imagery (CGI) requires many diverse resources. First, every film requires artistic and creative resources such as character animation, an interesting story line, set design and artistic direction. A 3D movie shares many features with a monoscopic film but also addresses additional issues. In order to tell a story in a 3D production, the director should be aware of narrative and 3D composition. For a 3D movie, the producer must also consider depth design, which is critical for effective stereoscopy. Each scene should be staged, not only according to the 2D compositional and narrative rules, but also to the level of intensity set for the depth. The director should be aware of the way 3D adds to the spectator experience; therefore, the stereoscopic effect should be increased or decreased according to the needs of the

scene. Indeed, viewers would not be comfortable experiencing an entire film in intense stereoscopy. Finally, each 3D production has a budget for stereoscopy which should be organized according to the needs of the script, regulating the 3D depending on scene conflict.

The problems associated with producing stereoscopic films are complex. Technical development is needed to provide the artist with tools to manipulate and to actually create the film. First, a typical 3D film requires double the resources as compared to a monoscopic film. Since a 3D effect must be rendered from two different points of views, two cameras must be placed in the scene with slightly different lines of sight, representing the right and left perspective views. In addition, each frame is rendered twice, demanding double the resources in terms of time and computation.

The objective of this work is to increase efficiency and efficacy in the production and post-production stages of stereoscopic effects. This paper addresses this objective in two different parts: the 3D design or production and the post-production considerations. Methods and tools used within Maya will be described for the former while those within Nuke will be described for the latter. Problems arising from the use of a single stereo camera rig and a multiple camera rig will be explained. The Foundry Nuke will be used for dealing with stereoscopic footage in the compositing stage.

CHAPTER 2

BACKGROUND

The basics of 2D composition are vital in understanding stereoscopy and methods for working with it. A spectator viewing a 2D image is able to extract depth information about the scene without physically experiencing it. The viewer can interpret the image and obtain depth cues based on experience to develop an accurate perception of the 3D space.

In order to design stereoscopic imagery, one must first understand and master monoscopic composition and the importance of 2D cues. Monoscopic cues should be the starting point in creating stereoscopic products since they enhance the stereoscopic experience. A skilled stereographer should use 2D depth cues to manipulate, enhance or decrease the 3D effect. Additionally, a full range of 3D depth cues within stereoscopic works must also be considered. Understanding the potential of 2D depth cues in creating stereoscopic imagery is important.

2.1 Monoscopic depth cues

When the viewer sees a picture or a monoscopic film in the theater, the individual is able to recreate a 3D scene from it. If the human visual system perceives the world in 3D, how is it possible to observe a 2D image or movie and experience it as 3D? According to Gestalt theory humans store information in visual memory; therefore, the viewer uses his/her visual experience in order to recreate a 3D scene. Moreover, the human brain extracts, compares, and contrasts 2D cues in order to be able to build a 3D

scene. Such 2D cues include the following: perspective lines, relative size, texture gradient, occlusion and atmosphere medium. Each of these cues will be discussed in the following sections.

2.1.2 Perspective lines

Lines that are parallel in the physical world will not remain parallel when projected onto the retina. Rather, they converge towards infinity (Figure 2.1). This convergence of parallel lines provides an important cue to depth, and was an important innovation by artists of the Renaissance. In order to infer depth from this cue, however, the brain must assume that the lines are actually parallel in the external world [Olsh12].



Figure 2.1: *Perspective lines*

2.1.3 Relative size

The human experience provides the spectator with information about the sizes of objects. By comparing and contrasting objects, relative sizes of objects can be inferred. “If you see a picture of a man and a skyscraper, and they both look the same size in the frame, you can safely assume that the building is farther away” [Men09].

2.1.4 Texture gradient

When a viewer observes an object, he/she can extract information about its texture. The distance from the point of view determines the amount of detail that is possible to extract. If an object is located near the point of view, more detail of its texture can be extracted, such as bumpiness or pattern. As the distance increases, fewer details will be observable.

For example in Figure 2.2, the entire path is composed of a rock material; however, the rocks closest to the camera exhibit the highest level of texture detail.



Figure 2.2: *Path walk texture*

2.1.5 Occlusion

Occlusion indicates relationships between objects based on blocking views along lines of sight. If one object is located partially or totally in front of another object, the closer object will prevent the visibility of the object located behind. In Figure 2.3, the red rectangle is occluding the second; therefore, the apparent depth suggests that the red rectangle is closest to the point of view.



Figure 2.3: *Cubes occlusion*

2.1.6 Atmospheric medium

Atmospheric media affect the perception of objects since the farther an object is located from the viewer, the less saturated its color and the less detailed its surface. In addition, the object's detail will tend to decrease as well. In Figure 2.4 the atmospheric medium results in a gradual loss of object detail in, and eventual loss of, visibility as the distance increases from the point of view.



Figure 2.4: *Forest fog*

2.1.7 Motion parallax

Motion parallax can occur either through movement of the point of view or by movement of the object. In the former a viewer extracts depth information about objects according to the distance they appear to be moving from the point of view. One example of this phenomenon would be viewing external objects from a moving train. Objects that are closer will appear to be moving much faster than objects that are more distant.

Parallax induced by an object's movement occurs when the point of view is static and the target is in motion. One example of this phenomenon is a plane takeoff sequence. When the plane is on the runway, it appears to move quickly, but when it is in sky, its movement appears slower.

2.2 3D stereoscopic depth cues

In order to create a stereoscopic experience, 3D depth cues must be implemented. These concepts create the 3D effect in a degree depending on setting and in combination with 2D cues. Topics associated with the perception of 3D depth cues will be discussed in the following sections.

2.2.1 Interocular separation

Interocular separation is the distance between the left and right human eyes. The default separation distance is 2.5 inches, though this number is not fixed and varies from person to person. A similar concept in film production is called interaxial separation, which describes the distance between the centers of two cameras lenses used in filming stereoscopic footage. Interaxial or interocular separation will affect the perception of a given object. If the interaxial distance is greater than 2.5 inches, the object will be distorted by hyperstereo or dwarfism effects and will cause the object to have rounded edges. At the other extreme, if the distance between the two points is less than 2.5 inches, the result will be a hypostereo or gigantism effect. Finally, if the interaxial separation is set to 2.5 inches, the result is termed orthostereo, which is an effect similar to human vision.

2.2.2 Retinal disparities

By using both eyes as viewpoints, a human is able to extract depth information by comparing and contrasting two slightly different points of views. This concept is termed

retinal or binocular disparity. In CGI this concept can be illustrated by analyzing a pixel across two stereo frames, where the binocular disparity is represented by the amount of pixel shift from one view to the other.

2.2.3 Vergence, convergence and divergence

In order to see, the human visual system requires muscular effort to focus and rotate the eyes in opposite directions. Vergence is the point where the viewer focuses his/her eyes. If an object is located close to the viewer, his/her eyes will need to rotate in opposite directions inward in a process called convergence. If an object is far away, the eyes will rotate outward in opposite directions in a process called divergence. When creating stereoscopic imagery, convergence and divergence points from shot to shot are critical; otherwise, the result may be a poor 3D effect, or worse, an extension beyond the safe convergence point, which can produce nausea, ghosting or headache.

2.2.4 Accommodation

Accommodation is the distance at which the eyes fixate to maintain clear focus. In 3D projection, the eyes accommodate to a flat screen, but the convergence and divergence points will be in front or behind the screen. This concept is important because in order to experience a 3D effect in the theater, the spectator must force the visual system muscles to accommodate the 3D effect, which can sometimes cause visual fatigue.

2.2.5 Positive, negative and zero parallax

Positive parallax occurs in stereoscopy when objects appear to be located behind the screen. Negative parallax is the opposite: the objects will appear to be located in front of the screen. The negative, positive and zero parallax points are determined by the convergence point. Figure 2.5 illustrates this concept graphically.

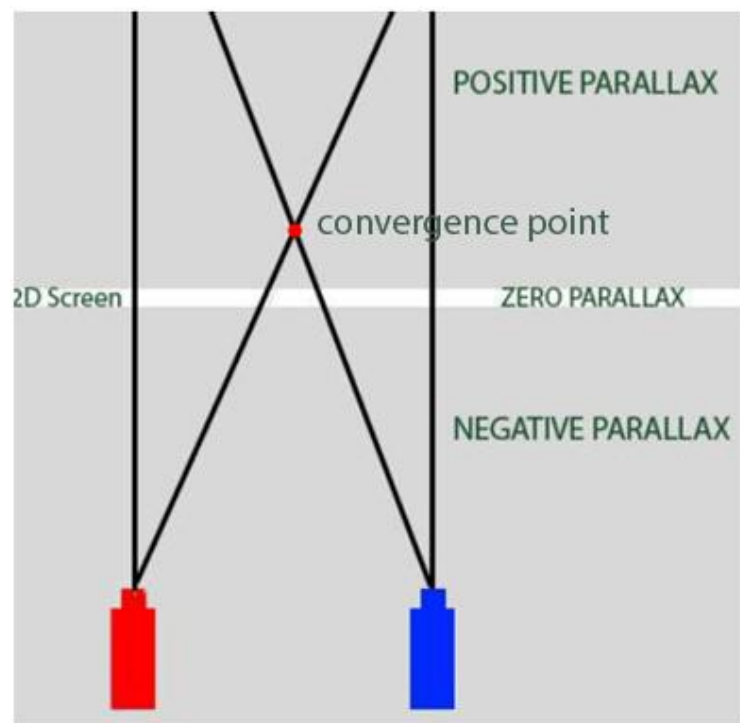


Figure 2.5: *Parallax map*

2.2.6 Retinal rivalry

Designing stereoscopic imagery has limits due to stereoscopic depth cues. On one hand, 2D depth cues are almost unlimited, as viewers are able to extract depth information from objects closer or farther away. 3D depth cues are limited and require careful design since some areas will not allow a viewer to extract 3D depth. In CGI, these

retinal rivalry areas must be avoided. If objects are located in such areas, the result will be poor 3D effects or worse, a painful experience for the viewer. Figure 2.6 explains this concept graphically [Men09].

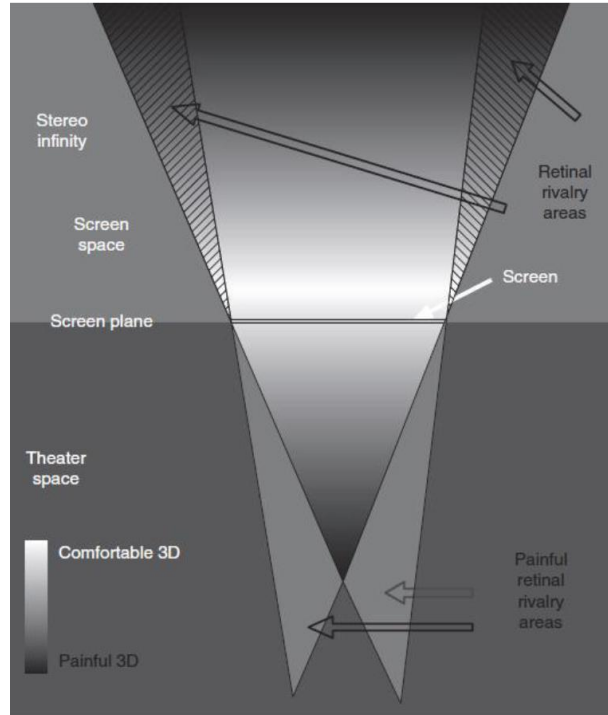


Figure 2.6: *Safe stereo map*

2.2.7 Anaglyph filters

The method for visualizing stereo effects in productions discussed in this paper is anaglyph filters. After rendering the left and the right views, the two are combined with an anaglyph filter. Figure 2.7 shows the left and right images along with an image where the anaglyph filter is applied.

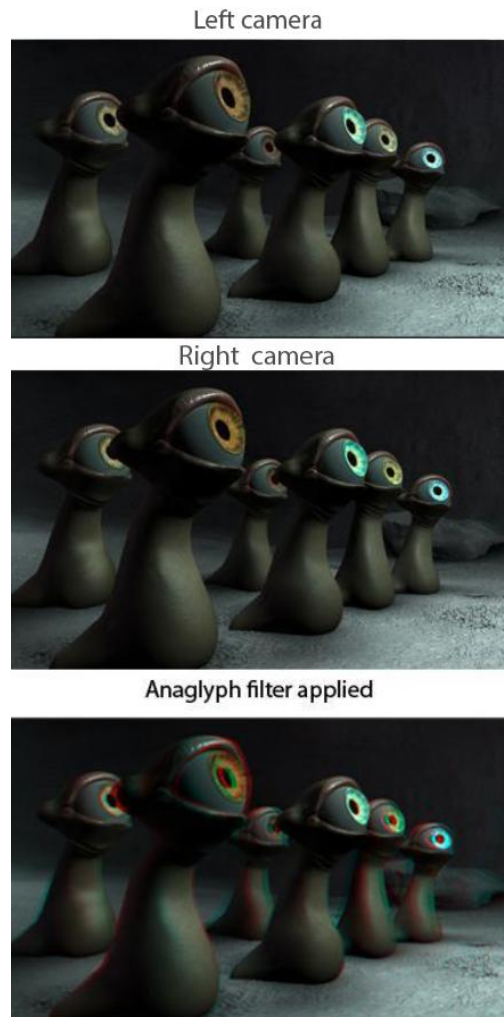


Figure 2.7: *LiFe in stereo*

The function of the anaglyph glasses filter is to prevent the visualization of specific color ranges to each eye. The red filter in front of the left eye extracts only the information of the left view, and vice versa. The user fuses both images mentally and experiences a 3D effect. Figure 2.8 shows a pair of anaglyph filters.

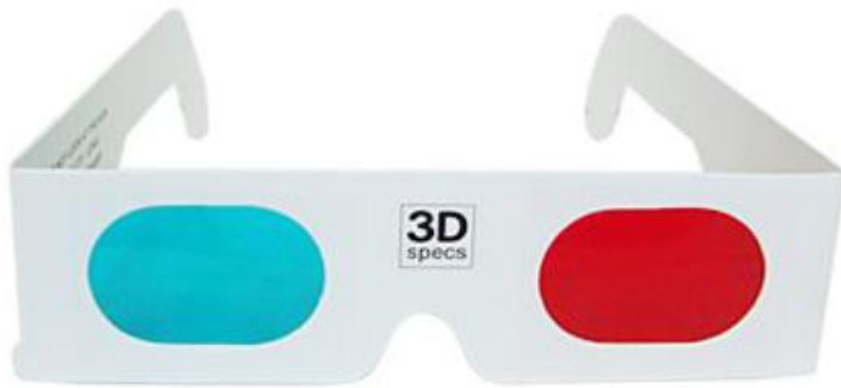


Figure 2.8: *Anaglyph filters*

CHAPTER 3

IMPLEMENTATION

This paper approaches the creation of stereoscopic imagery as a pipeline composed of a production and a post-production stage. The work presented is the result of production experience from the short films *LiFe* and *Spider Fight*, two very different projects, each requiring its own approach for creating stereo. Both projects, however, share the same need of an efficient pipeline that is easy to implement in production.

3.1 Introducing methods for production of stereoscopic imagery

Creating stereo 3D is a difficult task. While the underlying theory may seem relatively straightforward, implementation is complex for direct and indirect reasons related to the process. Some of these reasons are addressed in the following discussion

First, the stereoscopic effect will be perceived by the viewer differently according to the position that he/she is located in the projection room, both in terms of distance from the screen and orientation to the screen. The screen size also plays an important role in stereo experience. For example, perceived 3D volumes will be quite different on a 21” plasma TV than and on an IMAX screen.

The stereo production should consider the filter that the viewer will use for the stereoscopic reception. If the viewer uses anaglyph glasses, the 3D designer should create the stereo with this factor in consideration. Each filter represents a unique stereo type. Although the results will be similar, the visualization of 3D stereo using anaglyph will

differ if the audiovisual product is viewed with another filter type. Each of these elements is important and plays a critical role in the stereo final product.

In order to achieve the best possible result, the stereo production in this work was optimized for screening on a *Hewlett Packard* Monitor model *HP 2159m* with a 21-inch diagonal full HD LCD Monitor, as shown in Figure 3.1. The stereoscopic final product can then be easily viewed on other computer screens and experienced as intended. Additionally, 3D effects should be designed for a viewer located approximately 20 to 28 inches away from the screen, as seen in Figure 3.2.



Figure 3.1: *Stereo device*



Figure 3.2: *General viewer*

Two filter options are available for this projection: shutter and anaglyph glasses. As stated previously, selecting the filters before producing the stereo is critical. Shutter glasses produce a more effective 3D experience due to their advanced technology; however, such displays work only for a single person and not for a group, which is definitely a drawback. Anaglyph glasses were therefore chosen due to their portability and low cost.

3.2 Software selection

3.2.1 Autodesk Maya 2012

Choosing the correct software is also important when producing stereoscopic animations. The short films *Spider Fight* and *LiFe* were both produced in monoscopic format using Autodesk Maya 2012; therefore, using the same 3D software for the stereoscopic production was reasonable in order to avoid conflicts in exporting data to different applications.

3.2.2 Autodesk Maya camera

In order to effectively use the stereoscopic camera system that Maya offers, understanding how the virtual camera works is mandatory. Maya's virtual camera shares many of the attributes of a real camera, such as focal length, aspect ratio, lens distortion and f-stops, among others. A virtual camera is able to emulate a real world-camera, but also includes specific parameters such as near clipping plane, far clipping plane, film back, film aperture, focal length and film offset, which are described as follows:

Near clipping plane: closest point to the camera that is visible

Far clipping plane: farthest point from the camera that is visible

Film back: virtual film onto which images are projected

Film aperture: format of the projected image area, e.g. 35 mm, Academy, HD, etc.

Focal length: distance in millimeters from the camera to lens convergence point

Film offset: horizontal image translation in inches

Figure 3.3 illustrates the camera clipping planes [motion12].

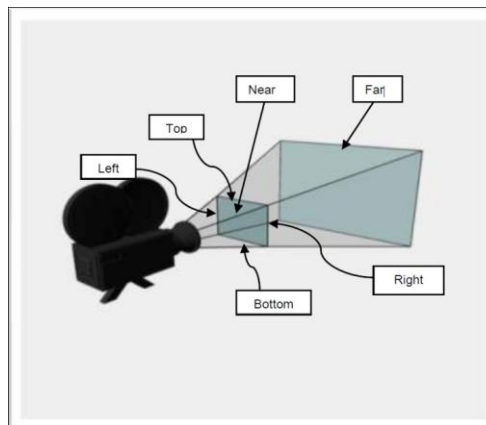


Figure 3.3: *Camera clipping planes* [motion12]

3.2.3 Maya stereo camera system

Maya's built-in stereoscopic camera rigs are efficient for creating stereoscopic imagery. Figure 3.4 illustrates a single stereo camera rig.

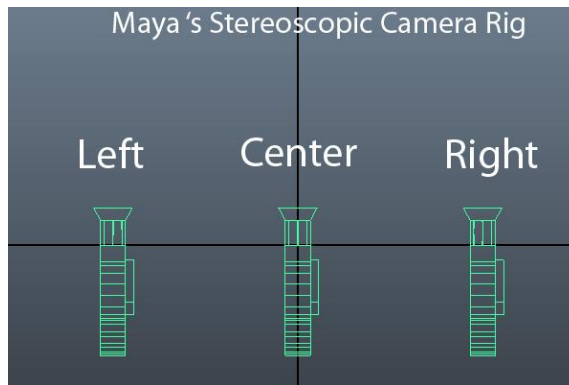


Figure 3.4: *Single camera rig*

The stereoscopic rig in Maya is composed of a group of three cameras. The central camera controls the following left and right camera properties: *translation, rotation, scale, focal length, near clipping plane, far clipping plane, vertical film aperture, horizontal film aperture, lens squeeze ratio and film offset*. Figure 3.5 shows the constraint properties of the right camera in Maya's Attribute Editor highlighted in yellow.

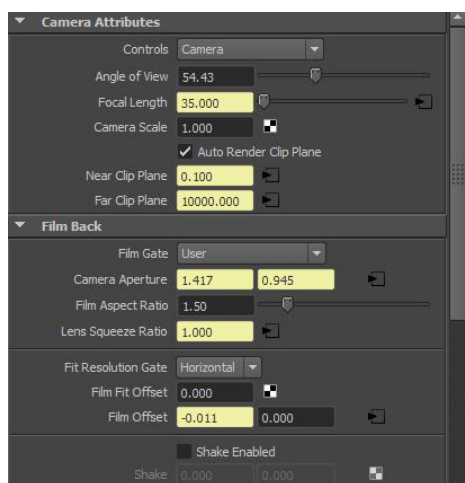


Figure 3.5: *Right stereo camera properties*

In addition to the previously listed properties, the center camera also controls the stereoscopic properties. Figure 3.6 shows the Attribute Editor of a single stereoscopic camera rig with the stereo controls that the center camera possesses.

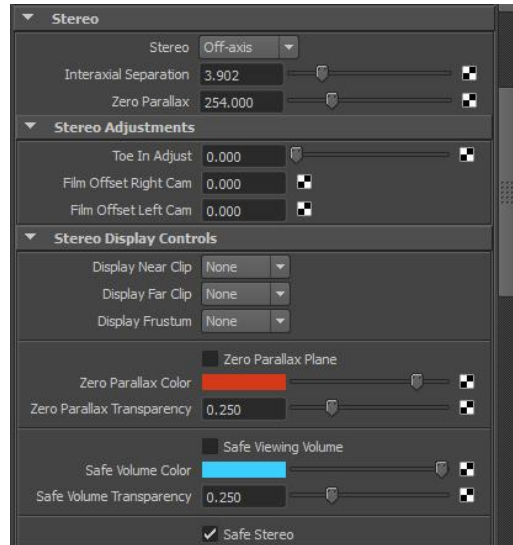


Figure 3.6: *Stereo attributes*

Maya provides different controls for creating and visualizing a stereo production. The center camera controls the interaxial separation, zero parallax and three different options for shooting stereo: off-axis, converged and parallel. These three settings refer to left and right camera alignment for capturing the virtual scene with each affecting stereo perception, production and post-production. The off-axis camera alignment sets the cameras in parallel position, with no rotation on the camera axes inward or outward. This method skews the film offset (Horizontal film offset), causing a convergence point when the zero parallax value is edited. Figure 3.7 illustrates this concept.

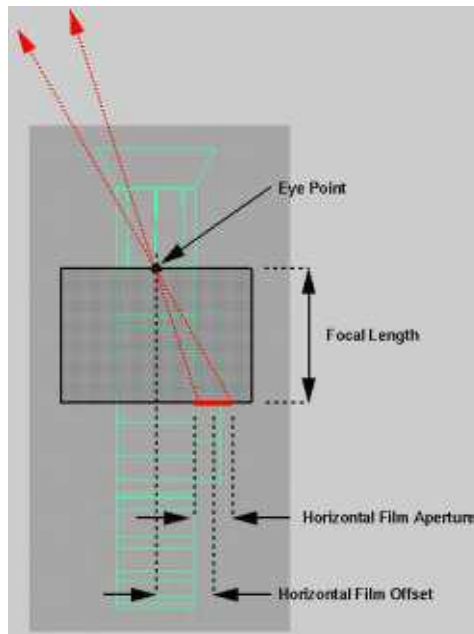


Figure 3.7: *Film offset* [motion12]

Figure 3.8 shows converged camera alignment, while Figure 3.9 shows parallel camera alignment. In the latter case, the camera arrangement has no convergence point, though it may be set in the post-production process.

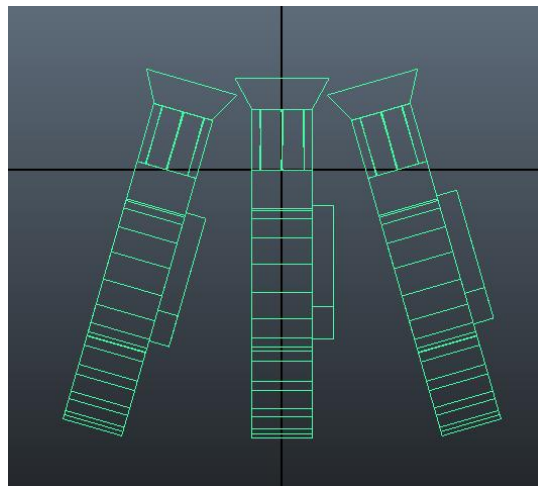


Figure 3.8: *Converged camera alignment*

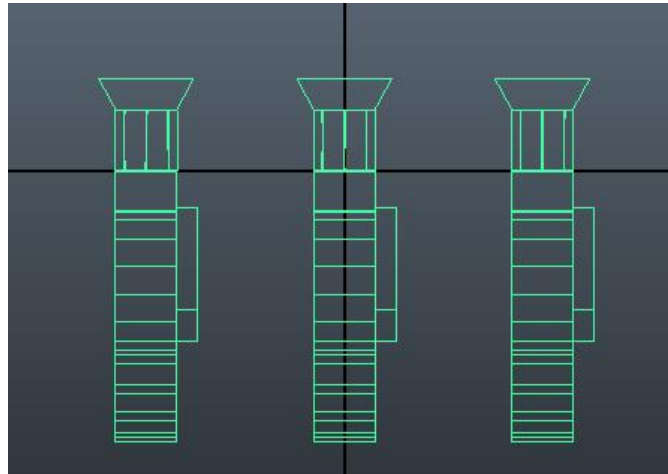


Figure 3.9: *Parallel camera alignment*

Another reason for choosing Maya was its rendering capabilities. In both projects, *Spider Fight* and *LiFe*, the rendering method was important because the final ensemble of the stereo footage was completed in a compositing package. Maya's rendering passes and rendering layers were used for the working revision and final assembly of stereo footage in the compositing stage. Finally, Maya is popular software in the 3D market and has many users worldwide; therefore, research and problem-solving information is easily found in forums as well as from experiences of other users.

3.2.4 Compositing package

The final stage of the stereoscopic production workflow involved compositing; therefore, another important decision was the selection of a compositing package. The available choices included Adobe After Effects and The Foundry Nuke since both packages are powerful and available for use. Initially the compositing was focused on

color correction and fixing footage problems in order to save time by avoiding re-rendering; however, since Nuke supports stereoscopic compositing, more of the stereoscopic work migrated to the compositing stage.

3.2.5 The Foundry Nuke

Nuke is a powerful compositing package with a node logic system similar to Apple Shake, where operations are represented by *nodes* which are categorized in a particular class, e.g., a file may be loaded with a Read class node. By default Nuke is set to monoscopic; therefore, the user must specify the project as stereo. This option will create left and right views for the project; otherwise, nodes using stereo will not work properly. Also Nuke possesses nodes specifically aimed at operating on stereo footage, such as filter classes which include anaglyph, sidebyide, splitandjoin and joinviews, among others. Moreover, Nuke supports the flexibility of applying effects to one view or both. For instance, applying color correction to the left and right Read nodes can be performed simultaneously or independently. Also, Nuke supports Python; therefore, creating plug-ins using the API or executing scripts using the script editor panel are also possible. Finally, the software possesses a 3D system enabling features such as importing geometry, importing cameras from 3D packages, using camera projection and adding lights or cameras to the scene. All of these features make Nuke an ideal option for this project. Figure 3.10 shows the Nuke interface, while Figure 3.11 shows different node type operations for stereoscopic footage on the Nuke node graph editor.



Figure 3.10: *Nuke interface*

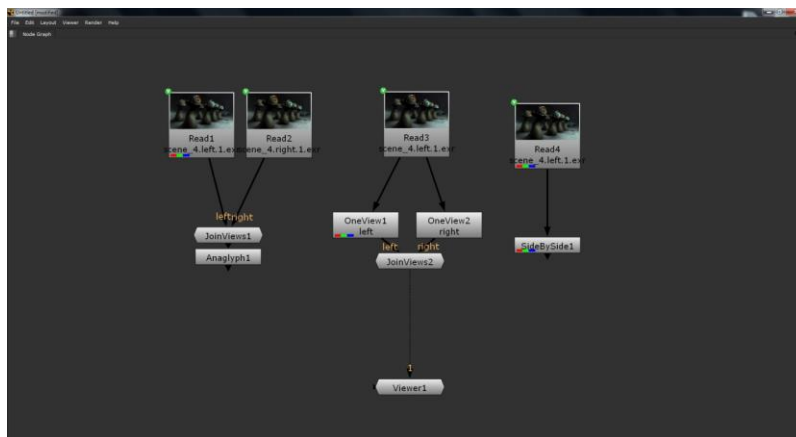


Figure 3.11: *Node operations*

3.3 Stereo production work for *LiFe* and *Spider Fight*

Depth design is a difficult technique to master and should be directed to aid storytelling. Furthermore, for a stereo 3D film, 2D composition rules are important because they increase or decrease the stereo sensation. Producing *LiFe* and *Spider Fight*

in stereo presented specific and dissimilar problems which led to different approaches for production and post-production of footage.

The *LiFe* and *Spider Fight* projects are cinematographically different. The former short film was composed of four camera shots while the latter was comprised of a single shot but contained intense camera animation. The stereo effects in both films were challenging to create. The basic idea of both was to create an audiovisual product in 3D stereo that enhances the visual experience in a way that is not distracting.

3.3.1 *LiFe*

The stereo 3D work for *LiFe* began with a compositing study. Analyzing the monoscopic composition of the scenes set up the initial background for working with stereo. Also, a diversity of shots in the sequence was important for designing the stereo effect. Figure 3.12 shows the shot sequence in order.

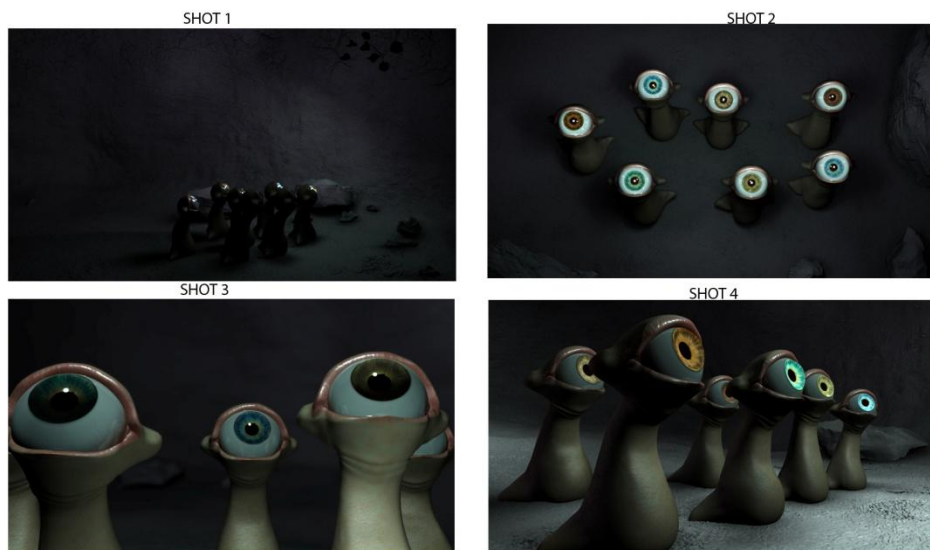


Figure 3.12: *LiFe* shot sequence

For designing the stereo in these sequences, a single stereo camera rig was set up with the focal length set to 25 mm. Even though this sequence is relatively short, the shots are diverse, which raises challenges in stereo design in terms of stereo continuity and consistency across the sequence. Specifically, while the first shot is a lateral extreme long shot with a still camera, the second is a long shot from a bird's eye view. Further, the third shot is a lateral medium shot travelling from left to right, while the fourth shot is a still lateral long shot with no camera animation. All the stereo theory rules were applied in order to produce an effective and enjoyable stereo experience. Additionally, each stereo setting takes into account the previous and next shot compositions in order to produce stereo continuity.

Visualizing stereo involves ocular muscular effort. Specifically, the viewer must rotate his/her eyes inward or outward to converge or diverge, respectively, to experience depth. The stereo designer must therefore rationalize the depth value of the shots to allow the spectator to relax his/her eyes. If the stereo is too pronounced, the viewer may suffer fatigue or headaches, and therefore, lose appreciation for the stereo experience. Since *LiFe* consisted of only four shots, the stereo was set deep, but overall, followed a depth increment across shots to enhance continuity and effect. A description of each shot follows, along with discussion of shot composition and stereo continuity.

3.3.2 *LiFe*: shot one

Shot one is an extreme long shot which sets the scene and introduces the characters to the viewer. Due to these elements, a clear visualization of the entire shot

composition was important. Stereoscopic design in this shot suggested small interaxial separation such that the 3D depth would not be exaggerated. Also, in extreme long shots, the interaxial separation should produce shallow effects in order to avoid divergence.

Figure 3.13 shows a frame for this shot with an anaglyph filter applied.



Figure 3.13: *LiFe: shot one*

3.3.3 *LiFe: shot two*

The second shot is completely different from the first. Specifically, the camera location produces a full or long shot with a high angle. The visual narrative is not interrupted; however, the change in stereo 3D setting may produce an interesting reaction from the spectator. The interaxial separation has been increased from scene one with zero parallax located right below eye level. This stereo setup allows the spectator to draw closer to the characters and their environment. While this shot did not present a difficult

challenge in stereo design, it represents an interesting and effective point in the story.

Figure 3.14 shows an anaglyph version of shot two.



Figure 3.14: *LiFe: shot two*

3.3.4 *LiFe*: shot three

This scene depicts a medium shot of the characters with camera animation that can be described as a crab dolly. While such animation can sometimes create issues for 3D stereo, this camera movement did not add any stereo complexity because the zero parallax was not changing on the Z axis; therefore, the depth was consistent. If the camera animation were a truck in, for instance, the zero parallax would be changing its Z axis, which might represent a problem if the convergence exceeded the safe stereo area (Figure 3.15), thus causing eye strain for the viewer. In this shot, the zero parallax is

located approximately midway between the first and second row of characters. In order to focus the spectator eye toward the characters, depth of field was added in compositing using the scene Z-depth pass.

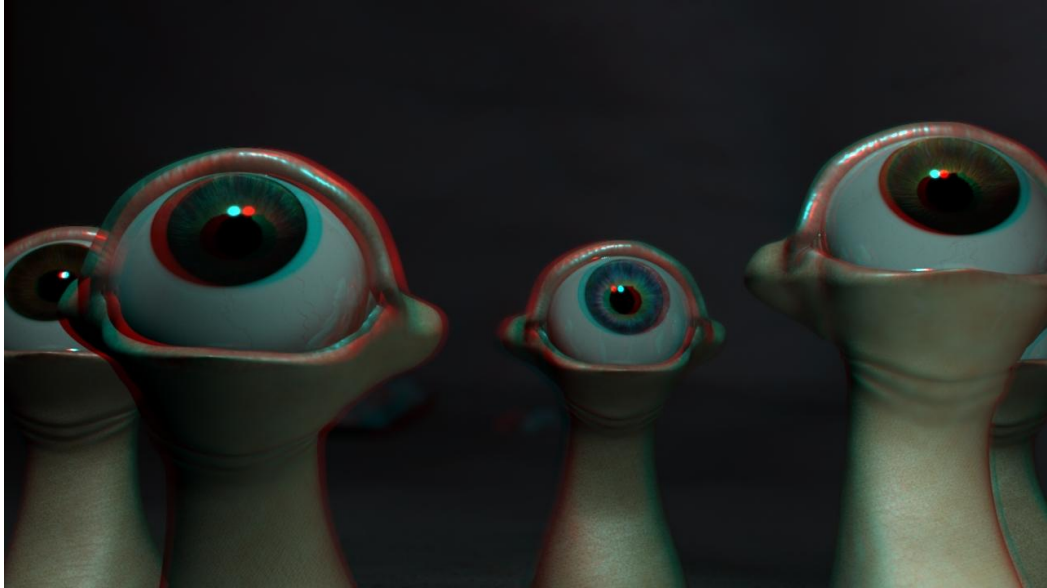


Figure 3.15: *LiFe: shot three*

3.3.5 *LiFe: shot four*

This shot was intended to be the climatic depth scene, when the spectator was transported directly into the midst of the characters. This scene, however, presented a problem because if the zero parallax point were set approximately to the center of the character's group, the closest and farthest characters in relation to the camera may produce eye strain. The solution was to set the characters in such a way as to form perspective lines toward the vanishing point, while also faking depth by scaling the character's size. Figure 3.16 shows a frame of this shot.



Figure 3.16: *LiFe*: shot four

Compositing all of the shots primarily involved color correction, depth of field and discrepancy fixes between left and right views. The stereo was designed in Maya and not modified in Nuke. The last production step involved editing the shots and rendering a single clip, which did not present further difficulty.

3.4 *Spider Fight*

The stereo 3D for the opening *Spider Fight* shot was challenging due to its monoscopic composition and camera animation. Even though this shot used only one camera, single-camera stereo would not be adequate for the manipulation required. Additionally, compositing was crucial in achieving the goals of this shot. In order to understand the challenge that this shot represents, the cinematography must be examined. The first part of the sequence uses a large field of view that shows a clearly defined

foreground, midground and background. The camera pans from left to right and begins to travel through grass until it rests on a full shot of the spider character on top of the spider web. Figure 3.17 shows the scene from the top view and an illustration of the camera position with a white icon. Also Figures 3.18, 3.19 and 3.20 show fields of view of the primary camera positions and their directions in order to convey the different planes that the camera will face during animation.

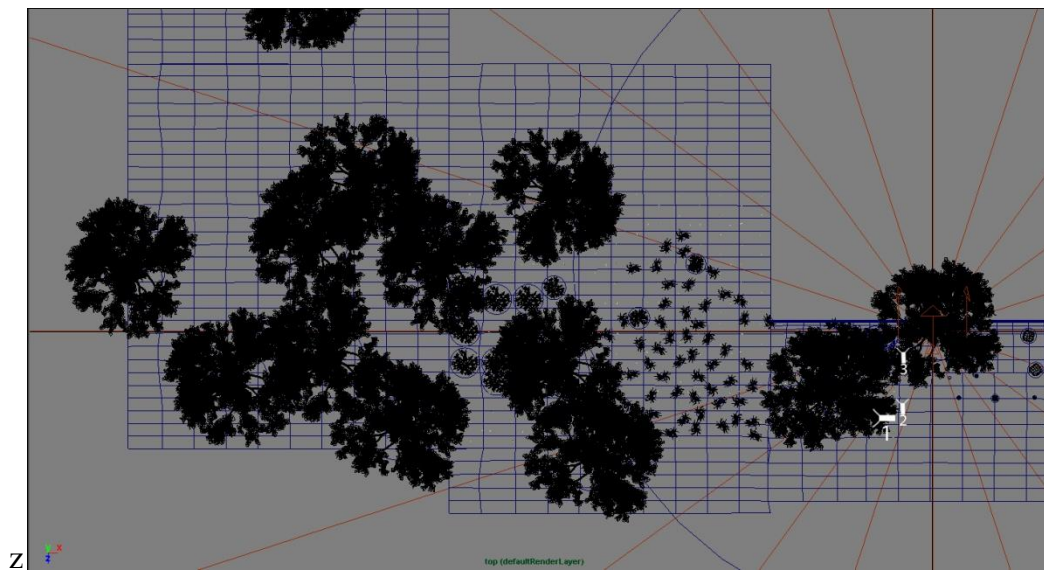


Figure 3.17: *Top view camera*



Figure 3.18: *Shot one field of view*

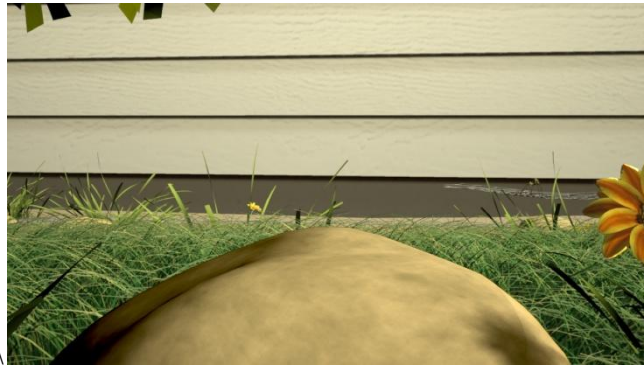


Figure 3.19: *Shot two field of view*



Figure 3.20: *Shot three field of view*

Moreover, Figure 3.21 shows a panoramic composition of the shot to emphasize the many different cameras encountered during camera animation. If this scene were approached using a single camera rig, the stereoscopic effect across different planes would be difficult to control. Using the multi-stereo-camera system allows the stereo designer to focus on just one of the composition planes, while the rest of the scene will be updated automatically. If the stereo designer decides to set a determined interaxial separation for the geometries that compose the foreground plane, the midground and the background will be updated automatically by this camera rig. By using the single stereo camera rig, however, the stereo designer is not able to control the stereo for specific parts of the scene.



Figure 3.21: *Panoramic view*

Obviously, the first goal of the stereo effect in *Spider Fight* was to eliminate any discomfort of the viewer. If this type of sequence were approached with a single-stereo-camera rig, many difficulties would be encountered, as evidenced by analyzing the initial shot shown in Figure 3.18. In this long shot sequence, bushes close to the camera

represent the foreground, the tree and the bushes nearby represent the midground, and the trees farther away compose the background. One important aspect to consider is that if the objects in the foreground exceed the safe convergence point, the result will produce uncomfortable viewing. Furthermore, if the objects located in the background exceed the divergence point, viewer discomfort will also result producing an unpleasant 3D experience. Further, the issue of objects exceeding the convergence or divergence points occurs multiple times during the shot sequence. Unfortunately, a single-stereo camera rig affects the stereo effect of all the objects in the scene; therefore, if the stereo effect increases to place the foreground plane on the negative parallax, other parts of the composition planes may exceed the safe stereo zone.

After such issues were considered, a new stereo solution using another approach was implemented. Fortunately, Maya offers a rig that fits well in this shot production: a multi-stereo camera rig. This type of rig is composed of a group of stereo cameras within a camera set. A “master” camera controls the rotation, location and scale parameters of the “slave” cameras, which are also termed “stereo camera layers.” One beneficial aspect of this system is that it allows the creation of a user-defined number of layer cameras. This system allows adjustments of different camera settings for any specific objects in the scene; therefore, in *Spider Fight* adjusting a determined stereoscopic property for an object in the foreground and another stereoscopic setting for objects in the background was possible. A positive aspect of using this system is that it allows isolated work on stereoscopic considerations, or any other parameter related to the camera, for a single object or groups of objects. If the camera is animated, other parameters might be

animated as well, including the zero parallax plane, interaxial separation and focal length, which may affect any individual or group of objects.

The developed system leverages Maya render layers, which allow objects to be handled according to user-defined groupings. This method was adopted in order to clearly define various groups of objects that will be rendered separately for a stereo composition. Figure 3.22 shows the camera rig that was used for working the *Spider Fight* sequence, while Figure 3.23 shows the scene layers.

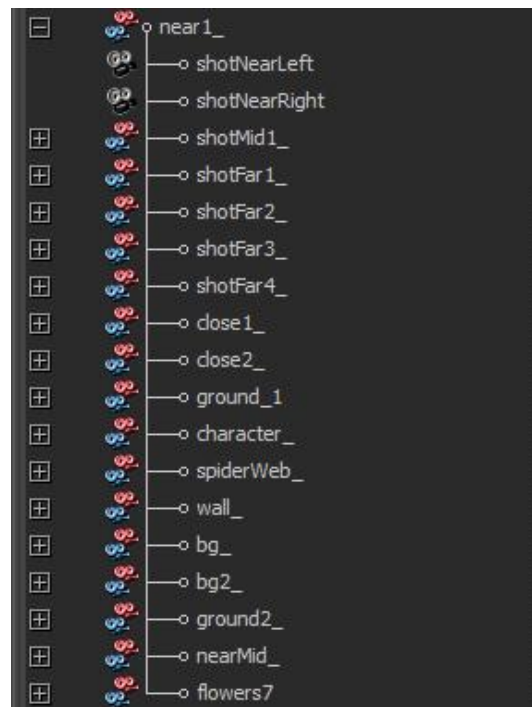


Figure 3.22 *Multi-stereo camera system*

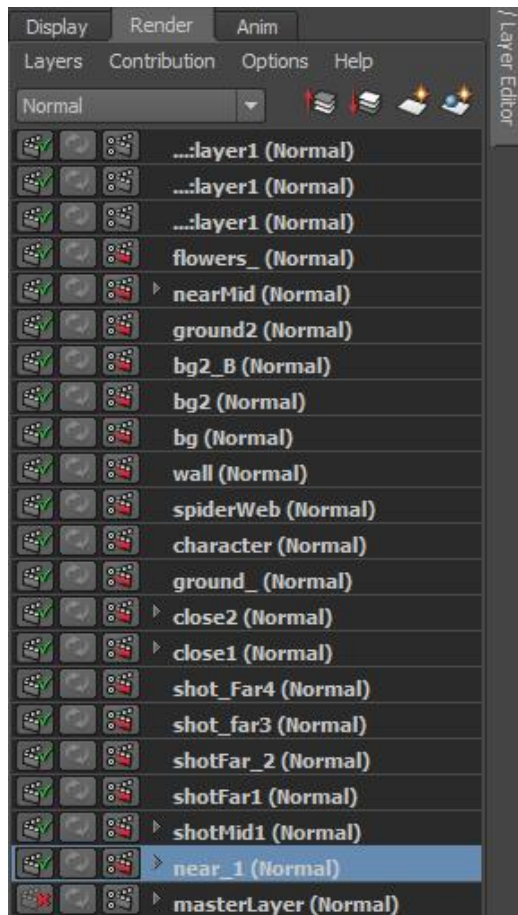


Figure 3.23: *Maya render layers*

In addition, each layer may have different settings to take advantage of layer overrides, which allows attributes to be set uniquely for each render layer. For instance, in this project each render layer had a different layer override regarding the camera assigned for rendering. Also, assigning different render pass properties, such as beauty, diffuse and ambient, is possible. Since each layer is rendered separately, all layers must be re-assembled in compositing.

This layering system approach enhanced control over objects. Figure 3.24 shows the *Spider Fight* Nuke compositing tree, which includes not only options for performing color correction, but also for solving problems regarding interaxial separation using a Nuke transform node as shown in Figure 3.25. This system will not, however, fix major issues resulting from the initial stereoscopic settings.

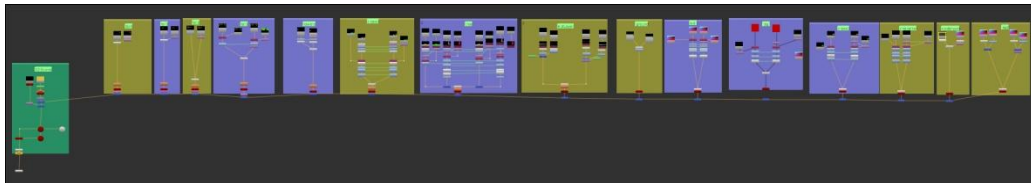
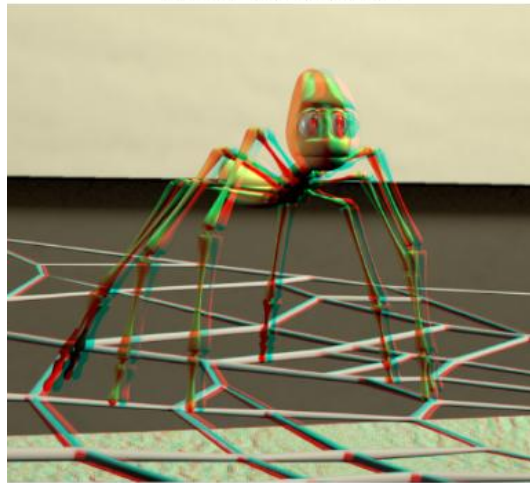


Figure 3.24: *Spider Fight* Nuke script

ORIGINAL OUTPUT



CHARACTER TRANSFORM MODIFIED

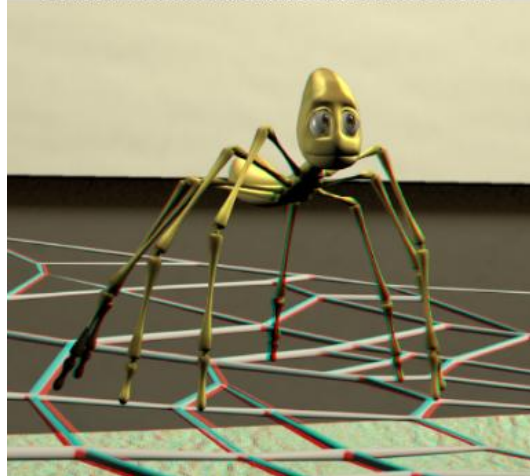


Figure 3.25: *Stereo interaxial separation editing in Nuke*

Finally, Nuke was used in the production of *Spider Fight* to solve problems regarding compositing issues. For this phase, the left and right layers were placed using a 3D card node, which allowed the footage to appear in a particular position in the 3D virtual environment.

The concept behind the 3D system was to facilitate creation of the sky and a light for compositing purposes. Finally, a Nuke virtual camera was added to visualize the entire composite, as shown in Figure 3.26.

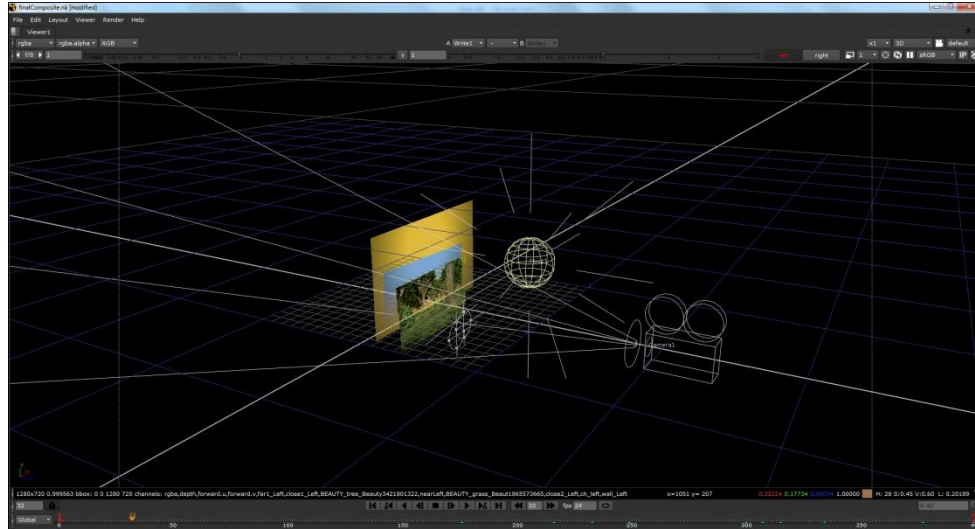


Figure 3.26: *Nuke 3D* system

CHAPTER 4

RESULTS

4.1 *LiFe* final output

The stereoscopic output of the short film, *LiFe*, is shown in Figures 4.1, 4.2, 4.3 and 4.4. All shots are shown with an anaglyph filter.



Figure 4.1 Final render of *LiFe*: shot one



Figure 4.2 Final render of *LiFe*: shot two



Figure 4.3: Final render of *LiFe*: shot three

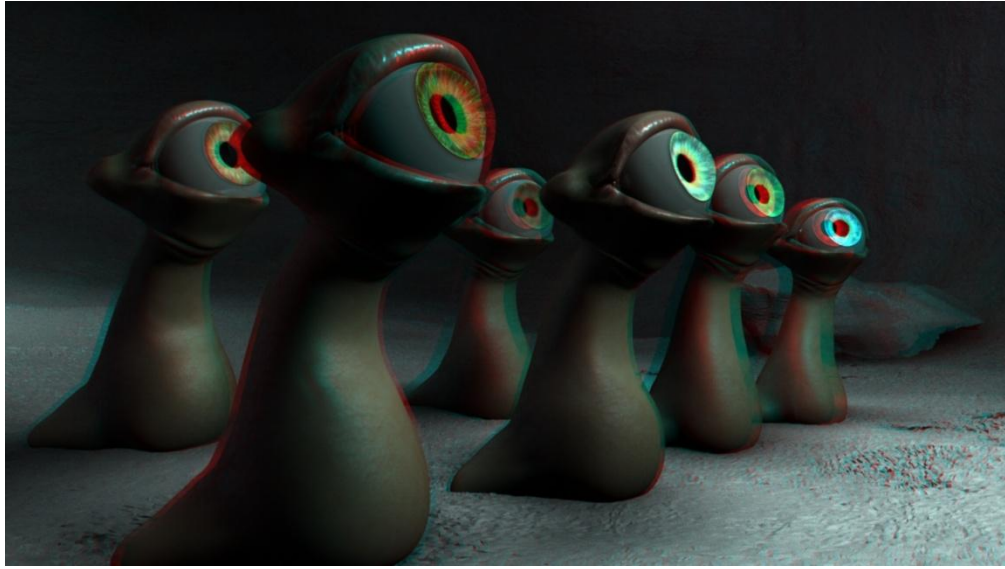


Figure 4.4: Final render of *LiFe*: shot four

The results from the style presented suggest that stereo 3D can be effectively achieved as a post-production process. Technology has facilitated the resurgence of stereoscopy, and technology will continue to drive its development in the form of methods or tools for working with and editing stereo effects.

4.2 *Spider Fight* final output

The final stereo output for *Spider Fight* is shown in Figures 4.5, 4.6 and 4.7. The results met expectations, but the technique could benefit from further refinements. To increase efficiency, a Python tool was created which consolidated all the necessary tools in one physical panel, as shown in Figure 4.8. The multi-stereo camera system continues to be refined. Figure 4.9 shows the current version of the stereoscopic tool.



Figure 4.5 Final stereo for *Spider Fight*: part one



Figure 4.6: Final stereo for *Spider Fight*: part two

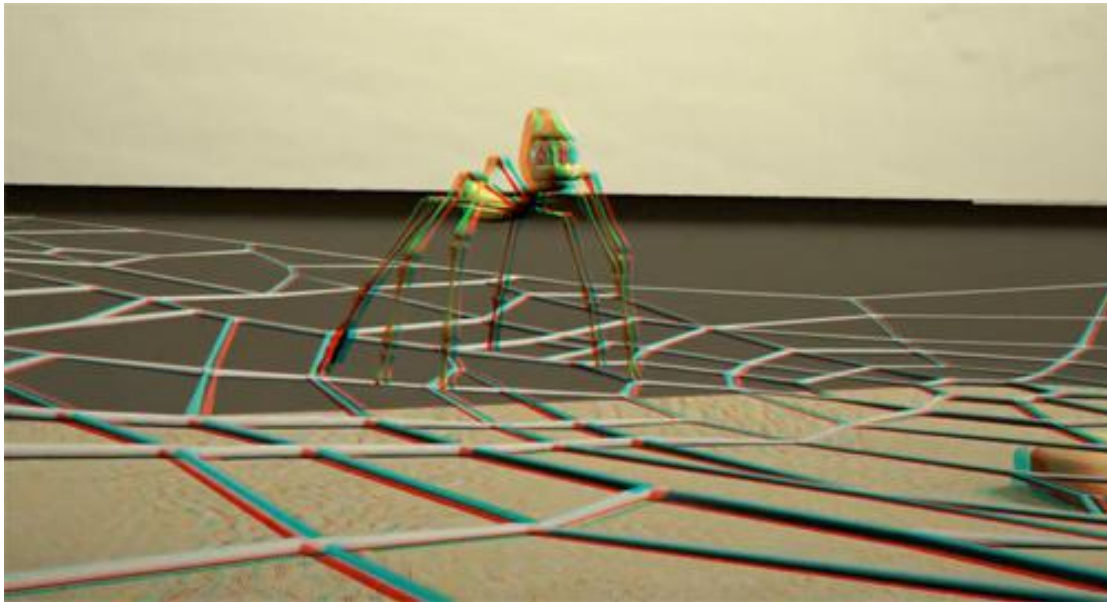


Figure 4.7: Final stereo for *Spider Fight*: part three

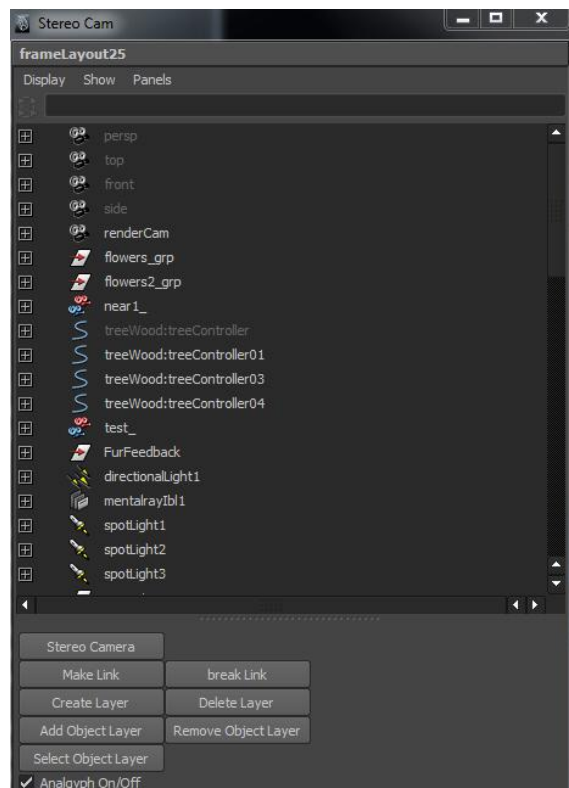


Figure 4.8: *Stereo panel interface, version 0.5*

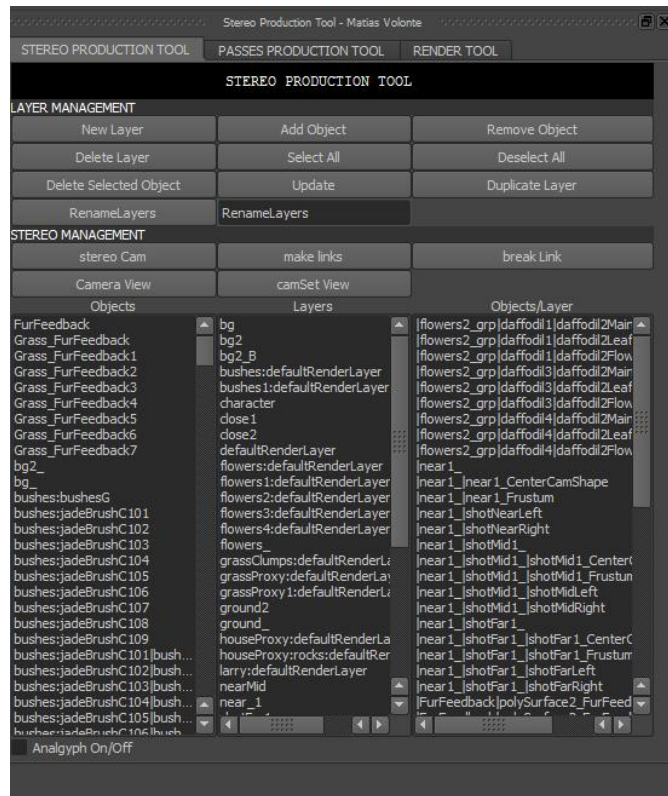


Figure 4.9: Stereo panel interface, version 0.9

CHAPTER 5

CONCLUSION AND FUTURE WORK

At present stereoscopy is mainstream not only in movie theaters, but also in student and amateur reels. This paper details an introduction of stereoscopic production methods that facilitate stereoscopy which can otherwise be complex to perform effectively. Often the differences between good stereo and bad rely on tool development.

The evolution and growth of stereoscopic tactics, from *LiFe* to *Spider Fight*, highlight the importance of detailed methodologies and tools to control the stereo effect. Tool development that enhances performance to parametric and mathematical guidelines will result in tighter stereoscopic consistency throughout sequences of varying shots.

Another approach that should be explored is working with the stereoscopic effect directly in Nuke. Building camera rigs using Python and placing rendered images on 3D cards can be leveraged to work with its powerful 3D system, which also facilitates traditional compositing.

The final product would produce a better output if more time were directed toward research and software development. The stereoscopic tools used for this project are aimed at enhancing the artistic side of stereo filmmaking, while accounting for the mathematics and science of zero parallaxes, interaxial separation and focal length.

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