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DEPARTMENT OF WEB AND MULTIMEDIA

Bachelor's thesis

Filmmaking for hemispherical dome

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Declaration

I hereby declare that the presented thesis is my own work and that I have cited all sources of information in accordance with the Guideline for adhering to ethical principles when elaborating an academic final thesis.

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Abstract

In this thesis I present the immersive environment and spherical films. I discuss both technical and artistic differences between classical and spherical films. I introduce the technologies that allow creating a film projected into a dome and I compare them. I also make on overview of existing spherical films and then I create one myself, walking readers through the entire process of making a full dome animated 3D film from scratch using one of the technologies presented earlier. In the end I project my film in a planetarium, discussing the practical principles of spherical films.

The thesis provides an overview of a new and rapidly growing media that definitely affects the film industry. It describes each step of the process of creating a spherical film with all the struggles and joys and it gives a direction to filmmakers who would like to start making spherical movies.

Key words   Immersive environment, spherical films, full dome projection, spherical mirror, planetarium.

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Abstrakt

V této práci představuji imerzivní prostředí a sférické filmy. Řeším jak technické, tak umělecké rozdíly mezi klasickými a sférickými filmy a porovnávám jednotlivé technologie, které tvorbu filmů pro dómy umožňují. Také představím několik existujících sférických filmů, a pak sama jeden vytvořím. Provedu čtenáře celým procesem tvorby 3D animovaného sférického filmu úplně od začátku, za použití jedné z předem představených technologií. Na konci svůj film promítnu v planetáriu a diskutuji principy fungování sférického filmu z praktického hlediska.

Práce tedy představuje přehled o novém, rychle se rozvíjejícím médiu, které rozhodně ovlivňuje filmový průmysl. Popisuje jednotlivé kroky tvorby takového filmu se všemy obtížemi i radostmi a dává tak návod filmařům, kteří by rádi do tvorby filmů pro imerzivní prostředí pronikli.

Klíčová slova   Imerzivní prostředí, sférické filmy, full dome projekce, sférické zrcadlo, planetárium.

Contents

Part I: Immersive environment

Chapter One: Introduction

Going to the movies is an inherent source of entertainment for many people. Considering that the number of those people was and still is pretty high, it is worth investing in technologies that make the experience in the cinema better for the audience. Cinemas focus especially on making the picture bigger, clearer and of better quality. The size of the screen has a huge impact on the level to what spectators get absorbed in the movie. Compare your feelings after seeing a movie on your laptop and after leaving an IMAX theater. This is the reason a new generation of visual projection has been developing for the past few years and it is still on the rise. It is the large scale immersive theaters. In these theaters audience get to see a pretty extraordinary spectacle, because they are in an immersive environment. An environment that surrounds them and literally absorbs them. The projection is happening on the inner sides of the hemisphere inside which they are sitting. Such projection is special because it does not have any frames, no limitation. When you look around, most art works are projected in frames, whether the frame is a TV screen or a computer monitor or a picture frame in a gallery. These frames suddenly disappear and the spectator becomes a part of the action happening around him. If the image moves, the audience move too, it is a very suggestive experience. Planetaria have been offering that kind of experience for years, they are projecting night sky in domes, which is an ideal projection for such environment. But the projection does not have to be limited to stars and constellations.

These days something called *spherical films* is being produced. These films, projected in domes and inside of hemispheres installed in theaters, offer a new way to enjoy modern digital media [10].

Challenges

Creating a spherical film is both technical and artistic challenge. Making a film in high resolution with extremely wide field of view means high requirements on imaging systems. Such projection in a planetarium must have more than 200 million pixels. In comparison with today's HD television standard, which is 1080i – a little over 2 million pixels, it is a hundred times more. However an acceptable quality can be reached with 4 million pixels as well and there are systems that can manage a projection of more than 8 million pixels. During the spherical projection itself either a set of precisely calibrated projectors is used, where the final panoramic view is created by merging and blending together images of each projector, or one special projector, which can project a fisheye image, is used. The preparation process of creating a spherical film includes warping the image, blending the edges of each image segment and separating images into channels that are played synchronously later [10].

The artistic challenge is to use and benefit from all the characteristics of a spherical projection. Immersive environment has a more intense impact on people that a flat screen and the

filmmakers need to learn to handle such media. The film language has been developing over a hundred years and it was adapted to framed projections (TV, monitors, cinema screens). The directors learned to use that frame for their narrations, they controlled the spectator's focus. A new media without any frame came and new ways to communicate with the audience came with it, so the film narration has to adapt. The audience is no longer observing the projection through an imaginary window. Suddenly they can be pushed through that window right in the middle of the action. The question and the challenge is how to present the action.

Goal

The goal of my thesis is to figure out not only technically but also artistically how spherical films work and then create a spherical films myself using all the special features that this media offers. In the first part I focus on theoretical research and understanding the technology behind spherical film. The second part is dedicated to practical point of view of creating a spherical film from scratch. I describe in details each step of the process. And finally part three is about projecting my film in a real planetarium, learning from mistakes and really understanding the principles of an immersive environment.

Chapter two: Development of the immersive environment

Brief history

It may come across as a surprise but the first art displayed in an immersive environment happened 30 000 years BC. It was the paintings in the caves of Lascaux, Chauvet, Verona and others. These prehistoric caves were the immersive environment, surrounding people, letting them experience those hunts portrayed on the walls over and over again.

Figure 1: *The cave of Lascaux*

1500 years BC ancient Egyptians and other ancient civilizations such as Greeks and Romans a couple hundred years later, were also creating immersive environments. They were building giant palace complexes with tall decorated pylon gates and peristyles that were making people feel small. The first architects who used domes instead of post and lintel architecture, were in ancient Rome. Those domes were representing heaven.

Figure 2: *Temple of Amon-Ra, Karnak*

Inspired by the Romans, renaissance architects of the 16th century started building domes as well. Probably the most famous one is in the St. Peter's cathedral in Vatican. They were also building vaulted ceilings and painted the insides which created another example of art in an immersive environment. The painting techniques in renaissance were focusing on tricking people into thinking that the wall paintings were real, this technique is called *trompe d'oeil* and with those skills, artists got to completely change the visual appearance of the inner architecture. The Room of

the Giants in the Palazzo Te is a great example.

Later in the 18ᵗʰ century, artists were creating large diorama paintings to make a bigger impression on people that regular framed pictures hanging on the walls. Louis Daguerre, the father of photography, created diorama theaters using large paintings in the early 19ᵗʰ century.

Figure 3: *Room of the Giants by Giulio Romano, Palazzo Te in Italy, 16th century*

Figure 4: *Louis Daguerre, panoramic painting*

At the end of the 19th century the Lumiere brothers patented a *cinematograph* and film became a strong, dynamic, storytelling medium. Film evolved into wide screen and later into more immersive formats.
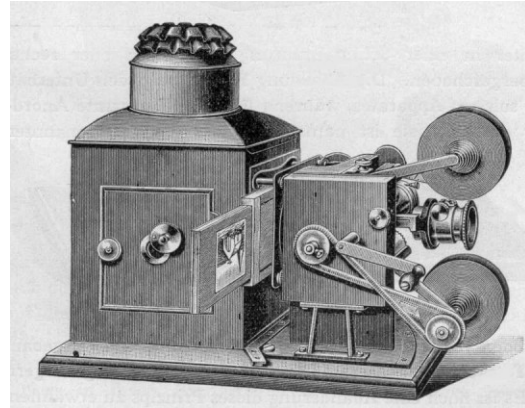

Figure 5: *Cinematograph by Alfred Wrench*

Figure 6: *IMAX cinema, 21st century*

Basic forms of planetaria

Simulator rides – the dome is placed almost vertically in front of the auditorium with seats in rows one above another [9].

Omni Large-Film Format Theaters – the dome is tilted (usually 30°) and placed above the auditorium with elevated rows of seats [9].

5

Planetaria – the dome is placed horizontally above the auditorium where the seats are in one plane [9].

Digital Dome Manufacturers [9]

- Evans & Sutherland – Salt Lake City, UT
- GOTO Optical – Japan
- Spitz, Inc. – Chadds Ford, PA
- Sky-Skan – Nashua, NH
- Trimension, Inc. – Burgess Hill, UK

Digital Dome Theaters [9]

- AMNH/Hayden Planetarium – New York City
- Bibliotheca Alexandria – Alexandria, Egypt
- Burke Baker Planetarium – Houston, Texas
- Exploration Place – Wichita, Kansas
- National Space Centre – Leicester, UK
- LodeStar Planetarium – Albuquerque, NM
- Madame Tussaud's – New York City
- Northern Lights Centre – Watson Lake, Yukon
- Volkswagen's Autostadt – Wolfsburg, Germany

Chapter three: Principles of an immersive image

The audience is inside the image, they are surrounded by it and they can watch the projection without any limitations or frames [15]. That is the main difference from a classical cinema where spectators are clearly said where to focus their attention through the frame of the screen. When projecting a film in an immersive environment you have to find a way to tell the audience on which part of the image to focus. As a spherical film is a different media from a classical film, the same thing applies to its film language, that has to change as well. The frame of the screen has always been a key element for an artistic composition and people got so used to it that they stopped noticing it. But the frame is still there and has a function. Cameras, projectors, screens, monitors, storyboards, everything is in frames, but you can not make a spherical film in rectangles. So how to make a composition without the frame?

Size

The answers is *size.* Immersive environment enhances every movement, making an object bigger or smaller in a spherical film has a different effect on the audience than in a classical cinema film. Because watching a subject enlarging towards a frame feels different than watching the same subject enlarging towards spectators themselves. They feel like they are moving along with the objects, everything feels more real [15].

Zoom

This brings *zoom* to question. Zoom in or zoom out is an important element of the classical film language. The director gets to control the details that he shows to the audience. But since the spherical film simulates real life, there is no zoom. If you move forward in real life, the objects in front of you get bigger but at the same time the objects behind you get smaller. Director of the spherical film can simulate zoom by moving the camera back or forward but he has to keep in mind that the whole scene will move, not only one fragment of an image.

Time and Speed

Another thing that feels different in the spherical film is *time* and *speed*. A gentle movement on a small screen can feel very aggressive in a large scale environment, it can even cause nausea [19]. When creating the spherical film, you have to think of time more carefully, you have to give the audience enough time to observe what is happening around them, because so much more is going on there than on a simple flat cinema screen. The communication with the spectators has to be delicate and well planned. They have a lot of possibilities were to look and if they are not told where is the main plot happening, they could get lost easily.

Music

Music is another element that can help with the narration. Sound in general can be a very powerful tool in an immersive environment. It could attract attention to a specific place, it could partly replace the zoom and, of course, if the music is well written it can intensify the experience in a positive way.

Generally having a great *imagination* is an essential skill for spherical movie makers. Because spherical movies are the real 3D movies, it is not a plastic effect on a 2D screen. It is real this time.

Chapter four: Standard spherical format & Projection

Spherical Format

When you are projecting inside of a hemisphere you need to have your footage prepared in a specific format. It is basically the surface of the sphere unfolded into a 2D grid. Such format is called an *imersoid* and it is independent in relation to any projection geometry [11]. You can create either a *cylindrical format*:
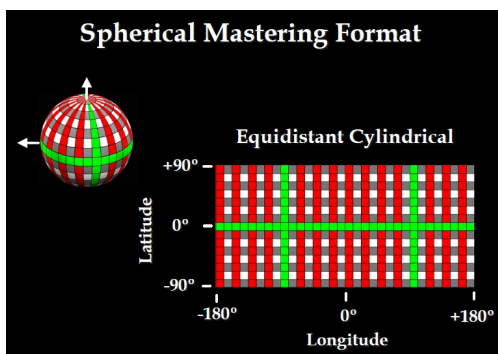

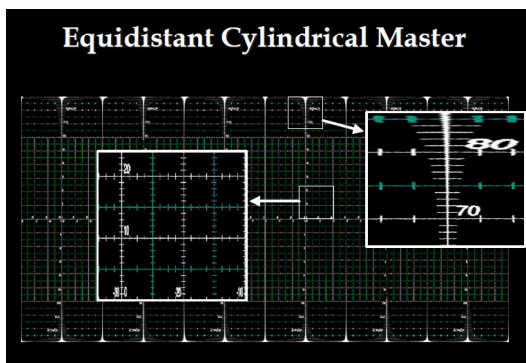**Figure 7:** *Standard spherical format, cylindrical*

Figure 8: *Cylindrical format, distortion*

In the cylindrical format the whole top and bottom line is mapped into one pixel representing the north and south pole of the sphere. See in Figure 8, how the pixels along the edges adapt to that, the whole area is distorted [11].
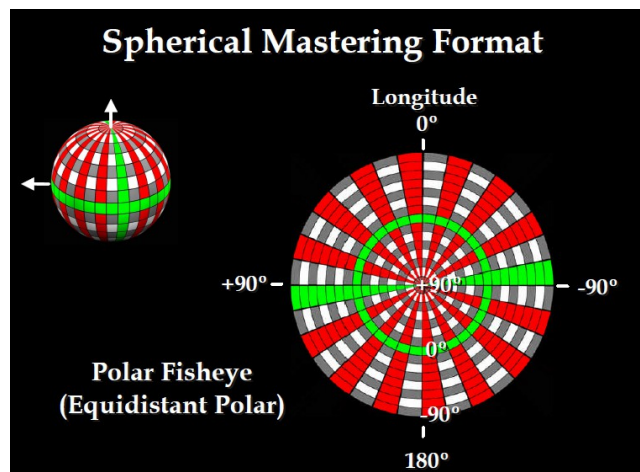
Or you can create a *polar fisheye format*:

Figure 9: *Standard spherical format, polar fisheye*

In the polar fisheye format it is the perimeter of the circle that maps into one pixel. See in Figure 10 what the distortion looks like. The distortion is more significant than in the cylindrical format. The cylindrical format is also more economic, you can see that it takes half the pixels as the fisheye format. The fisheye format leaves the corners of the image unused, which is a waste [11].
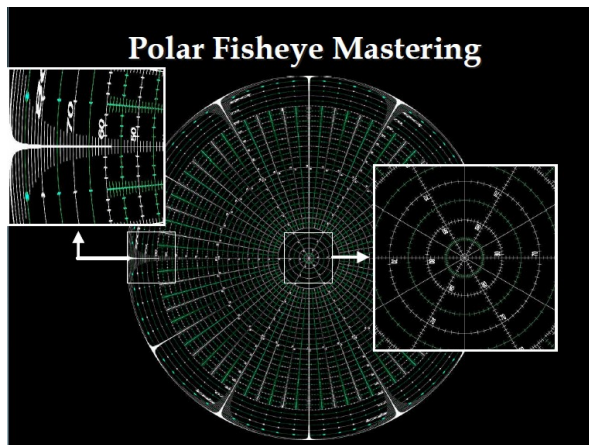
Figure 10: Polar fisheye format distortion

Figure 11 shows what an actual film content looks like when converted into a fisheye format. The location of objects makes sense but the severe distortion of the edge makes the picture hard to read [19].
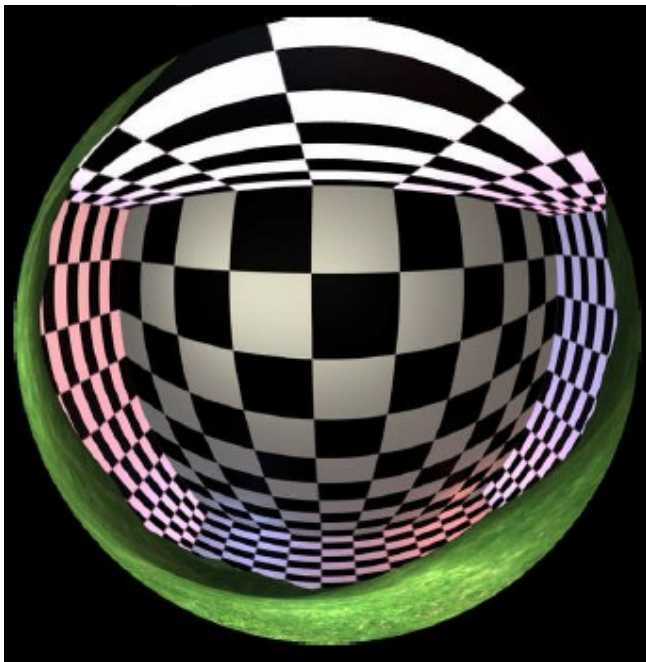

Figure 11: Polar mapping

The cylindrical format is not as distorted as the fisheye image however it is hard to understand the placement of the objects in that format. It is cut in the middle so two objects that are projected next to each other actually can appear on the opposite edges on the cylindrical format [19]. See Figure 12.
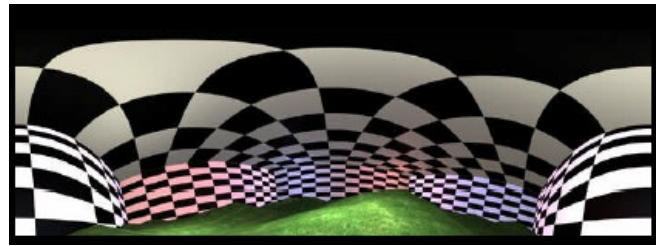

Figure 12: Cylindrical mapping

Projection

For the actual projection you can either use one projector that is capable of projecting the fisheye format or use multiple calibrated projectors when each of them projects a sub-image cut from the original fisheye or cylindrical format.
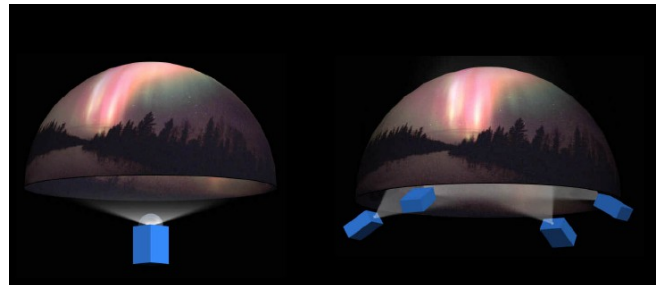

Figure 13: Spherical projection

The advantages and disadvantages of using a fisheye projector are [11]:

- Easier configuration of the projector since there is only one
- Limited hemispherical resolution
- The projector is placed in the center of the theater, facing upright, which can be disturbing for the audience, let alone it

takes the best seat from them

The advantages and disadvantages of using multiple projectors and composing the final image by blending together fragments of each projector [11]:

- Depending on the number of projectors, this method offers practically unlimited resolution for the final image
- Optional field of view
- The original standard format has to be cut into fragments, the edges have to be blended and warped
- All the projectors need to be precisely calibrated in terms of colors and brightness
- This method is more complicated and way more expensive, depending on the number and quality of the projectors

Figure 14 shows the fragments created by cutting the fisheye format into sub-frames for four projectors.
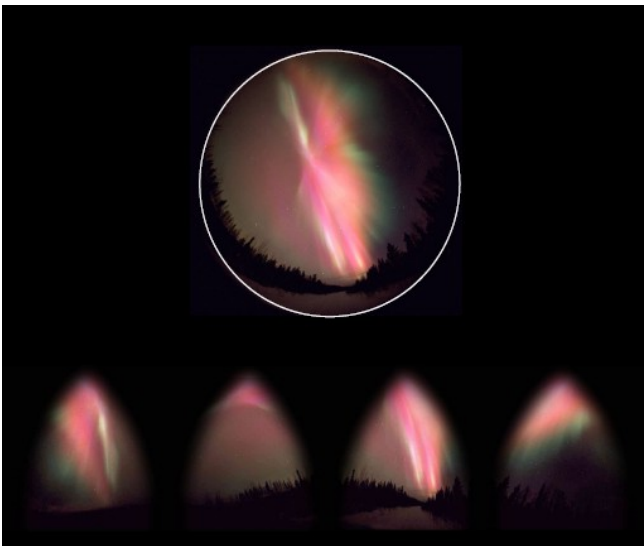

Figure 14: *Cutting the fisheye format into sub-frames*

Both of these projecting methods offer great results and high quality images, however they are both very expensive so I did not get a chance to project my movie using any of these two. Luckily there is a third method of projecting a spherical content and that method uses one projector and a spherical mirror. This is the method that I used when creating, testing and projecting my own movie.

Paul Bourke's Spherical Mirror

The spherical projections used to be limited only to big planetaria where public astronomy classes took place. They were projecting stars and constellations on the dome screen using various kinds of projecting hardware such as star projector, laser projector or multiple projectors composing the final image by blending the sub-frames. Lately planetaria moved it to another level and started projecting not only stars but also spherical films. Modern hardware even enables real-time projections so we are no longer limited to pre-rendered footage and we can create interactive spherical films. Unfortunately the costs of running such planetarium with all the equipment were too high. Luckily Paul Bourke introduced a whole new method to implement projecting in an immersive environment with similar quality but much lower costs. His method uses a spherical mirror [1].

Since the planetaria met with such a big success with spherical films, people started thinking of implementing similar projections in much smaller domes. These little dome theaters have about 10 meters of diameter and they are installed in scientific centers. But there are also domes of 5 meters of diameter and they can be installed pretty much anywhere. The difference

between these small dome theaters and big planetaria is mainly in the cost that the owners can afford to maintain the projecting systems. The alternative method of Paul Bourke significantly lowers the costs while keeping the quality and even brings some new advantages with that new system [1].

The spherical mirror can transform the image from a regular projector's frustum practically onto the whole surface of the hemisphere. There are many possibilities where to place the projector but in those small dome theaters it is usually placed by the back side of the dome. Which is a huge advantage compared to the fisheye projector which is placed right in the center and takes the best seat for watching the projection [1]. Figure 15 show the arrangement of the projector and the mirror in a dome.
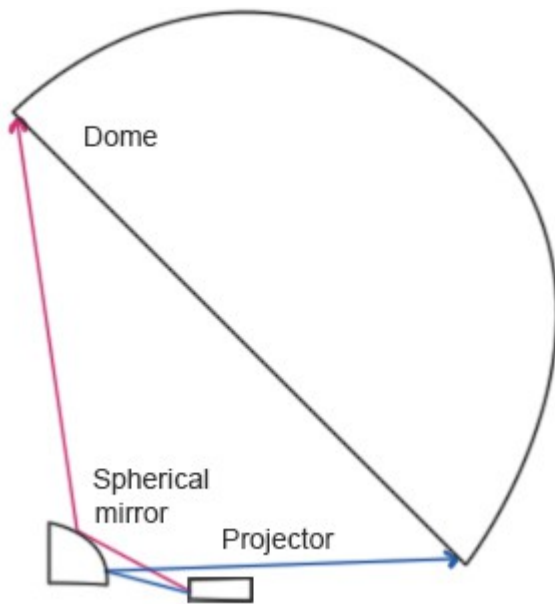

Figure 15: *Using spherical mirror in a dome*

The differences between a spherical mirror and a fisheye projector [1]:

- Location of the projector. As mentioned earlier in a dome this small, the ideal seat to watch a projection is in the middle of the dome which is exactly the place where a fisheye projector is placed. Unlike this, the spherical mirror and the projector are located by the back side of the dome and are not in anyone's way.
- The mirror and the projector are two separate units which gives the owner a wide range of possibilities when choosing a projector while there are only a few fisheye projectors.
- The size of the projecting area is customizable by changing the distance between the mirror and the projector or by changing the zoom of the projector. However it can never cover the whole surface of the dome but then again the fisheye projector does not project on the whole are either.
- The system can be adapted to a projection with two projectors and two mirrors and get a better resolution and quality of the pictures.
- Unlike the fisheye format which does not cover all the pixels of the square, the corners are left unused, the spherical mirror format uses the whole picture however not all pixels are used with the same intensity.
- The fisheye projector uses a polar fisheye format as its source picture. The spherical mirror uses a format that is created by warping the fisheye format. This is an extra effort compared to the fisheye projection.
- An often problem with the fisheye projection is a chromatic distortion on the edges. There is no such distortion with the

mirror projection.

- The angular lens for the fisheye projector is designed to be focused on all the points on a dome surface equally while the focus of the spherical mirror can vary depending on the distance between the projector and the points on the dome surface. But these flaws can be fixed by using a projector with a great depth of field.

It is obvious that the mirror projection is ideal for the small domes since it lowers the costs and preserves the quality. I projected my film in both, small dome of 3.5 meters diameter and a small planetarium of 10 meters diameter and I was very happy with the method. It is very simple, the only disadvantage was that one extra step of warping the fisheye format. I will get to that in more details in the practical part of my thesis.

Chapter five: Examples of spherical films

Journey to Infinity (40min)

This film was created in 1998 by the Evans & Shutherland manufacturer and it was the first spherical film for StarRider Interactive. They enter a new field and had to show effective methods of producing a real-time film. In the process of making the producers found new ways to create models, environments and interactive scenes in real time for full dome projection. The film is about a spaceship that takes off to an interactive journey to the Solar System and explores the life in Space. The fact that the film is interactive only makes the experience more intense and spectacular. For the first time the audience could learn and be entertained in a fully immersive environment [2].
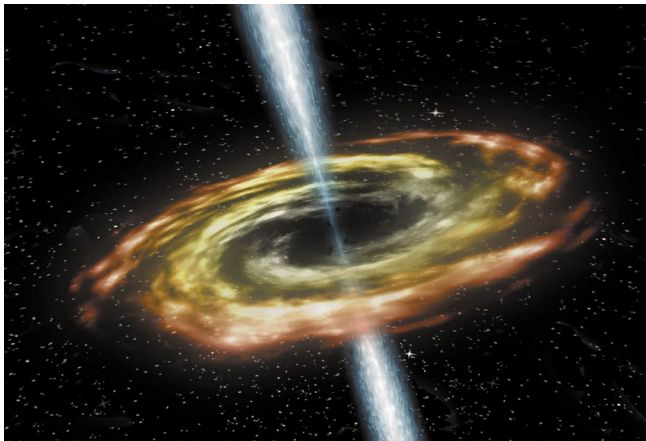
© 1998 Evans & Sutherland Computer Corporation. All Rights Reserved.

Figure 16: *Journey to Infinity*

Used tools:
3dsMax, MultiGen Creator, Adobe Photoshop, ACDSee, ProTools, Evans & Shutherland Showmaker, Evans & Shutherland REALImage PC Technology, Evans & Shutherland ESIG Image Generator, Evans & Shutherland DigiStar II Programming Language [2].

It Happened in New York (15min)

Film, created again by Evans & Shutherland was a huge attraction for the museum of Madamme Tussaud's in New York. This projection combines real life actors with a computer generated environment and it is about traveling back in time and showing the most famous celebrities of New York such as Elvis Presley [2].

Figure 17: *It Happened in New York*

Used tools:
Autodesk Maya, 3dsMax, MultiGen Creator, Adobe Photoshop, Adobe After Effects, BOXX Render Farm, Avid Media Illusion, Avid Media Composer, Evans & Sutherland REALimage Technology, ProTools, ACDSee, NameWiz, DeBabelizer, SkyStitcher, SkyVision Hi-Def Renderer, Motion Control, HDTV Video Cameras, Soundstages at Universal Studios [2].

PopMania! (24min)

This film was created by the Spitz, Inc. company and it combines a panoramic video, lasers and 3D animation. It introduces the audience to the world of the 20th century full of craziness and modernization. From Charlestone to Macarena, from hula hoop to Pokemons, it is a break through the events from the past 100 years. The film was created for the scientific museum in Kansas City, Texas and one of the biggest challenges was reformatting some of the footage that was originally made for a flat screen. And of course shrinking a hundred years into 24 minutes [2].

Figure 18: *PopMania!*

Used tools:
3DSMAX, ImmersaMax, Conglomerator, Billboard Filter, Maya, Maya Paint FX, Adobe Photoshop, Adobe After Effects, DeBabelizer, ProTools, Scitex StrataSphere, Scitex VideoCube, Adobe Premiere RT, PolyDome [2].

I really liked the idea of the last two films. I was not going to create an interactive spherical film. I was going to make a classic pre-rendered film. And I wanted to make it a journey through

time as well, presenting the most important events, people, inventions. But my film was all 3D animated, I did not combine any techniques neither did I use any footage originally for 2D. I created my film all from scratch and the second and third part of my thesis show each step of my work on that short spherical movie.

15

Part II: Creating a spherical film

Chapter One: Concept and Design

When making a movie, no matter how big, it is very important not to underestimate art preparations. There are certain steps that need to be followed before you actually start working on the movie itself. First you need to write a *movie pitch.* It is a short story describing the main plot of your movie. The purpose of the movie pitch is to attract producers and sponsors which means the shorter the pitch is the better because businessmen are always busy. Within a short amount of time you have to persuade them that your movie is worth investing in. The shortest movie pitch possible is called an *elevator pitch* and there is a reason for this name. Imagine that you are standing next to Steven Spielberg in an elevator and you only have this much time to tell him your story and get him on your side. This is how you write the elevator pitch. You build up the story upon this, add details, extend the story line, explain the story logic and turn the movie pitch into a longer piece, a *film tale,* which can be a few pages long. I combined the movie pitch and the film tale into one piece because my film is a student work, therefore I do not have any producers or sponsors, and it is so short that it does not need two pieces to describe the story. After finishing the film tale, you can start working on a screenplay. There are two types of screenplay, a literary screenplay called a *script* and a *technical screenplay.* The script is meant for the actors, it consists of all the dialogues and mis-en-scene of the story, it does not say how to shoot, it says what to shoot. It should give the reader a very clear vision of what the final film will be about. It is the technical screenplay that says how to shoot and it is meant for the film crew, especially for the director and the director of photography. It contains detail descriptions of each scene including camera movements, the lighting setup, sound edits, dialogues, timing and generally technical instructions for the film makers. The last but definitely not least step in the film preparation process is a *storyboard.* It is a picture screenplay. The technical screenplay tells us everything about each scene, what it should look like, how it should work but the storyboard shows us. Each scene is drawn by an artist to describe the visual image that will later be shot on the camera. It also contains dialogues and notes on the storyline and timing but it is technically not as comprehensive as the technical screenplay.

My short film is technically not as demanding as common feature films so I also combined the technical screenplay and the storyboard into one piece.

Movie pitch & Film tale

My film theme is "Time" and the first thing coming to my mind was time traveling. I find this topic very fascinating and even though I know that time travel is not possible, unless we find out how to level the speed of light, I still like to think about it. Maybe it is not possible in the real world but what about

our dreams? We can do anything in our dreams, especially when those dreams are lucid and we get to control the story. So I started picturing my film as a lucid dream. Keeping in my mind that I am creating a film for a full dome projection, therefore I have to adjust the form, I decided to place my story in a huge skydome. Literally a sky dome, I wanted my story to take place in heaven to create this dreamy atmosphere. The time traveling idea was not going to be as dramatic as in Hollywood movies, I was just picturing objects representing certain periods of the European history as they float between the clouds ostensibly in a chaotic order but they would always fly together to create a scene from a specific era. For example classicism – Mozart, Napoleon, a painting by Theodor Géricault and a classic building.

It seems quite complicated to create 3D models of Mozart, Napoleon and a classic building. But I was never picturing full 3D objects. First, it would take considerable amount of time to model and it would not even look good because I am not a professional 3D modeler. Second, it is a dream, things can not look too realistic, it has to be stylized. I decided to make all the models look like cardboard cuts. They would, of course, follow the shape of the object but they would be somewhat flat.

I also had to come up with an idea to use all the special features that spherical projection offers and enhance them. Make the audience feel like they are in the middle of action. Creating a spherical film needs a different approach than cinema films. Placing the story in the sky is the first step. There is no floor, no walls, the space is infinite. The second step is to form those objects into a circle flying around the dome making the audience feel like they are the center of the system. Like they are the Sun and the objects are planets. That way I do not have to animate the camera. It can be still all the time right in the middle of the circle. It is the objects that are moving.

Sitting in the middle of flying objects could be confusing, people would not know where to look, where to pay attention so I have to make it easy and understandable. The scenes or the views from the history will always be formed in the front part of the dome and while a scene is being formed the other objects would stop moving for a while.

This way I am planning on presenting 9 most important periods from our history: the Summers, ancient Egypt, ancient Greece and Rome, the birth of Christianity and Gothic, Renaissance, Baroque and Classicism, the 19th century full of industrial inventions, the 20th century with world wars but also great accomplishments and in the end, of course, the today's world.

Every movie needs an ending. It took me a long time to come up with and ending that would make people think. I decided that since I am in a lucid dream and I can time travel, I should go to the past as well as to the future, so the last scene has to be a vision of our future. My inspiration is two movies and one book. One of the movies is Interstellar by Christopher Nolan, reminding me of the second movie, 2001: A Space Odyssey by Stanley Kubrick. The book is The Day of the Triffids by John Wyndham. All these pieces have something in common, they are dealing

with our future not necessarily in a very positive way. The Day of the Triffids made me think about our civilization more than anything ever before. All those great civilizations such as the Persian empire, Ancient Egypt, Ancient Rome, they all fell apart, disappeared. We are probably approaching the same end, everything is speeding up, there are new inventions every day, people push the limits all the time and our life is hectic. We are going to fall apart as well. People in Interstellar try to solve the problem by leaving our planet and finding another place in the universe to live. But what if there is no such place, what if people will have to stay on the Earth and start over from the beginning? A very famous scene from Space Odyssey popped up in my head. The scene where a monkey discovers that a bone could be used as a weapon. What a great step in evolution. I decided that my last scene will be represented only by one object and it will be this monkey lifting a bone. I hope that after seeing the whole film, all those periods and civilizations, people will get my point when they see the monkey in the end.

Script

The main scene is placed in heaven, the audience is surrounded by a blue sky and clouds. Between the clouds, formed in a circle around the audience, there are objects in shapes of cardboard cuts representing different historical periods. There is no obvious connection between them for the first sight but when the music starts to play they come together and form a timeline which consists of 9 significant eras from our history. Every time a new era is presented, all the objects representing it come forward in the frontal part of the dome and float in the air, closer to the audience than the rest of the timeline. Then they come back, the timeline turns and a new scene comes forward. The order of the scenes and the objects representing them are:

1. Sumerian Empire
   This was one of the first ancient civilizations dated in the 4th millennium BCE. The representing objects are: *a mud plate with cuneiform, a stone calendar, a ziggurat, a Sumerian chariot with wheels, an Accadian sculpture.*

2. Egypt
   Another great ancient civilization, dated from the 3th millennium BCE till the 3rd century BCE. The representing objects are: *a pharaoh, queen Nefertiti, pyramids, Egyptian canon – a typical painting technique, a papyrus, a mud plate with hieroglyphics.*

3. Ancient Greece and Rome
   Great European civilization, they were an architectural inspiration for artists until the 20th century. Dated from the 8th century BCE till the 5th century AC. The representing objects are: *a sculpture of Caesar, a wooden Trojan horse, theater masks, the Colosseum, the bust of Aphrodite by Praxiteles.*

4. Early Christianity and Gothic
   A birth of the new religion spreading all around Europe followed by the Gothic period. Dated in the first 14 hundreds years AC. The representing objects are: crucified *Jesus Christ, crusades, a rotunda, the cathedral of Notre Dame in Paris, a drawing by Albrecht Durer, a golden altar.*

5. Renaissance
An era of the human mind and great discoveries. Dated in the 14th – 16th century. The representing objects are: *the Solar system, Sandro Boticelli's painting The Birth of Venus, Michelangelo's David, William Shakespeare's portrait, Leonardo Da Vinci's painting Mona Lisa, Leonardo Da Vinci's human study drawing.*

6. Baroque and Classicism
The culture keeps developing but there are also cruel wars and revolutions. 16th – 18th century. The representing objects are: *Wolfgang Amadeus Mozart, Napoleon Bonaparte, Eugène Delacroix's painting Liberty Leading the People, The Marriage of Figaro music sheet, the baroque church Basilica Di Superga Near Turin Italy, Napoleonic wars.*

7. The industrial revolution
The transition to new manufacturing processes. Dated from about 1760 to sometime between 1820 and 1840. The representing objects are: *a car, a train, Marie Skłodowska-Curie, an arc lamp drawing, Paul Verlain and Arthur Rimbaud, Claude Monet's Sunrise.*

8. 20th century, world wars
The most significant events for Europe in the 20th century were definitely the two world wars but also great inventions and journeys such as the first landing on the Moon. The representing objects are: *a rocket, Elvis Presley, Albert Einstein, Adolf Hitler, mushroom cloud, Pablo Picasso's Guernica.*

9. Today's world
We all know the world that we live in, the world of electronic devices, social media, robots, skyscrapers and outrageous artists. The representing objects are: the Facebook logo, the Google logo, an iPad, a robot, a city of skyscrapers, Miley Cyrus, the CGI (computer-generated imagery) of a monkey in the Dawn of the Planet of the Apes movie.

10. Possible future
Only one object appears on the scene. It was not anywhere to be seen during the whole movie. It pops out from behind of the picture of the CGI monkey and it is a picture of the monkey from the Space Odyssey movie looking at a bone, realizing that it could be a weapon. This last scene should make people think about our future. Question our actions, ask where we are heading. All the great civilizations from the past have fallen. Are we going to fall as well and start from the scratch?

Searching for music

When searching for music for a student film you have to be careful about copyrights. Unless you are willing to pay for the music for your film, you have to choose a free music.
I was looking for a relaxing, consistent but in a way driving soundtrack. Epic music, it is a recent name for dynamic tune used mostly for movie trailers, video games or sci-fi and fantasy movies. I downloaded four free tracks, all by Kevin MacLeod, that met my character requirements. Lithium [12], Decline [3], The Descent [17] and Undaunted [20]. This selection was eliminated to only two tracks,

Undaunted which I really loved and The Descent, an amazing piece as well. I had to decide which one to take. They were both longer than 3 minutes so I knew I was going to edit it because I wanted my film to be between 1 and 3 minutes. I chose Undaunted, it was a faster, more dynamic piece but when I cut it down to my required time it did not seem right. It felt exaggerated and the last thing I wanted for my film was to make it cheesy. Sometimes, when making an artwork, you have to let go off what feels like the best part to you, to keep the piece together. Because it may not be the best part in the end. So I replaced Undaunted with The Descent. The music is more continuous, without dramatic key changes or fast pace growth. It is more dreamy but still epic, that is exactly what I was looking for.

Editing music

The track The Descent was originally 3:11 minutes long and I needed to have it under 3 minutes. It is not easy to cut music and I do not like to do it because I have a lot of respect for music composers, but it was necessary. I listened to the track countless times, picturing my objects fly by, counting seconds for each scene and I decided that cutting the music under 3 minutes had to be done. In order to do that, you need to have at least some musical education because you can not just cut wherever you want and then glue parts together without thinking. Every music piece has a story, a beginning, an end, it speaks through musical phrases and if you are about to cut something out, you have to make sure, you are not dividing a phrase in the middle.
I used Audacity®   as my music editing

software. It is for free and offers all I need.
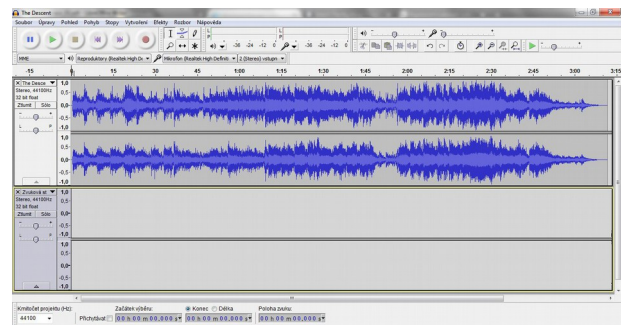
Figure 19: Audacity, The Descent

I imported the piece into the first stereo track and then created a new blank stereo track for the new, edited version. I only wanted to make one simple cut. If you look at the audio wave in Figure 1, you can see that there is a false ending before the second minute. The music seems to end but then it starts again. I decided to leave the final part off and replace the false end with the real one. That way the piece had only 2:29 minutes, which was perfect.
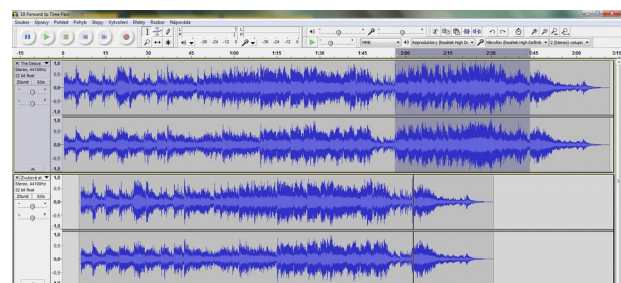
Figure 20: Audacity, The Descent after cutting

I made the cut very carefully and put the edited parts into the new stereo track and glued them together, which can be seen in Figure 20. Technically and musically the transition is unnoticeable. Of course, if someone knows the piece, he will notice that something in the end is missing, but other than that it should not be irritating. I did not throw the cut part away though. It was really nice and relaxing so I used

it as a background music for my subtitles.

Another part of editing my music was adding a clock ticking. My film is about time and since I decided not to put any dialogues or monologues into the sound part, I wanted the music to be more symbolic. I got inspired in the third Harry Potter movie, The Prisoner of Azkaban, there is a music piece called Forward to Time Past and it plays when Hermione and Harry use the Time-Turner to go back in time. At the beginning there is just the ticking and later it turns into music. I decided to put the ticking on the background of my whole piece, to enhance the rhythm. I recorded a few seconds of my grandmother's old alarm clock and copied it all along the stereo track. Then I had to match the BPM (beats per minute) of both of the music tracks. I didn't want to change tempo of my music piece, I wanted to adjust the clock ticking. There is a simple function in Audacity – Change tempo, where I entered the current BPM (60) and the required BPM (133) and it changed the speed of my ticking track.
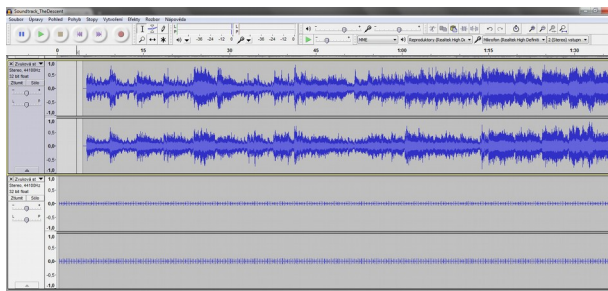
Figure 21: Audacity, The Descent with clock ticking

I had to make a few local adjustments to make sure the clock ticking fits and then I exported the project into the *soundtrack.wav* file. It is included on the attached DVD.

Storyboard

After editing my music I started working on the storyboard. It was important to have the music before the storyboard, because I was going to animate my film in the rhythm of the music. My soundtrack is not just a background music, it is a guiding music. First I created a timeline where I divided the track into several parts, each lasting about 10 to 15 seconds and described the scenes happening at a given moment. Then I created the storyboard with pictures to get the first visuals of my upcoming film.

Creating a storyboard for a spherical film is slightly different from a storyboard for a cinema film. Usually a storyboard consists of rectangular frames representing the screen where the film will be projected. In the end, no matter how many 3D effects a film has, it is always projected on a 2D rectangular screen. This does not apply to a spherical film where the final projection surrounds the audience. I had to figure out how to represent the hemisphere on a paper. I could have tried to draw into those rectangular frames and draw only those parts that the audience would see in the frontal part of the dome. But that was not enough, I needed to portrait every movement, every object all around. The solution was quite simple, the standard format for a spherical film is a circular fisheye picture. I turned rectangular frames into circular frames and drew in a fisheye perspective. It required a different type of imagination but I enjoyed it. I used my licensed version of Adobe Photoshop CS6 and my Wacom Intuos tablet.
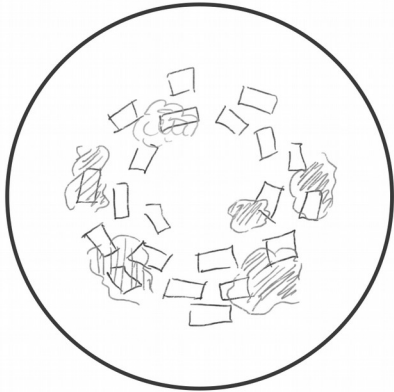
0:00 0:04

From 0:00 to 0:04 movement frozen.
All the figures are on the screen. At 0:04 movement begins. It's a chaos, all the figures are moving different directions but then they start grouping together to create the scenes on a imaginary timeline.

0:23

All the figures are setteld down and their movement is frozen. The Sumer figures are in the center front and they fly forward to present the first scene.

0:32

The Sumer figures fly back to the timeline which turns and moves the Eguptian figures to the center. They fly forward and present the second scene.

0:42

The Egyptians are replaced by the Romans and Greeks.

1:00

The Romans and Greeks are replaced with the figures from the early Christian period and Gothic.

1:14

The rise of Renaissance. There are planets orbiting the Sun, that should be a nice effect. From now on it starts to speed up.

1:24

Renaissance is replaced with Baroque and Classicism.

1:33

Baroque and CLassicism are replaced with the industrial revolution.

1:42

20th century replaces the industrial revolution.

1:56

Music calms down and figures from nowadays come to the center front.

2:10

The figures from nowadays start to fly back to the timeline. The future figure of a monkey holding a bone appears behing one of them and flies to the senter.

2:15

The timeline turns for the last time. The figure from the future stays still in the center front.

2:20

The figure from the future starts to fly back to the end of the timeline implying what the future could look like.

2:29

The music slowly stops, so does the last figure and everything stays still just like at the begining.

Figure 22: *The rough storyboard*

ACTION

Still picture, all the figures are on the scene in a chaotic order. Clock is ticking on the background. Waiting for the music.

TIMING

0:00 - 0:04
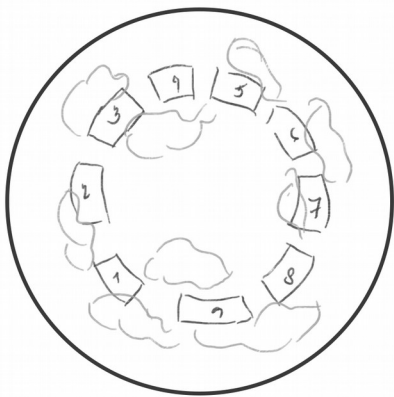
ACTION

All the figures start to move. They start looking for other figures from their period and while forming a scene from the past, together they form a circular timeline all around the dome.

TIMING

0:04 - 0:23
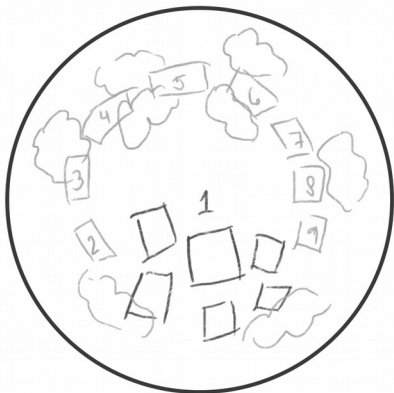
ACTION

The timeline turns to place the first set of figures to the center. It's the sumer age figures, they fly forward to create a scene in the center while floating in the air. The other scenes are back in the distance keeping low profile, ready to come forward.

TIMING

0:23 - 0:32

Figure 23: *Storyboard, page 1*
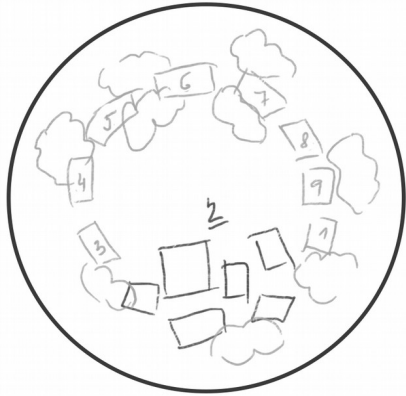
ACTION

The sumer figures fly back to the timeline and it all turns again. Egypt is now in the center, figures are flying forward to form a scene.

TIMING

0:32 - 0:45
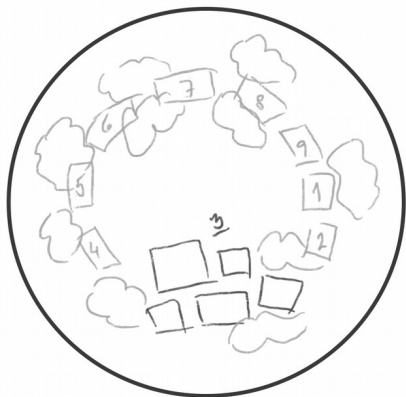
ACTION

The timeline turns again and Egypt is replaced with ancient Greece and Rome.

TIMING

0:45 - 1:00
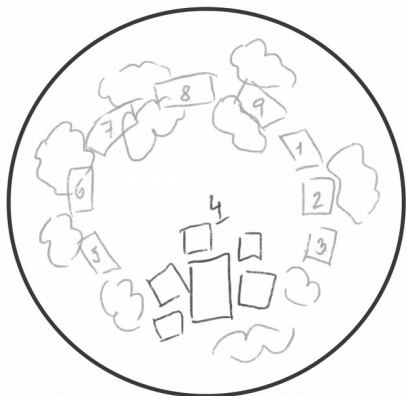
ACTION

Ancient Rome and Greece is replaced with early christian and gothic figures. The music is still pretty slow and calm, so is the movement of the figures.

TIMING

1:00 - 1:14

Figure 24: *Storyboard, page 2*

25
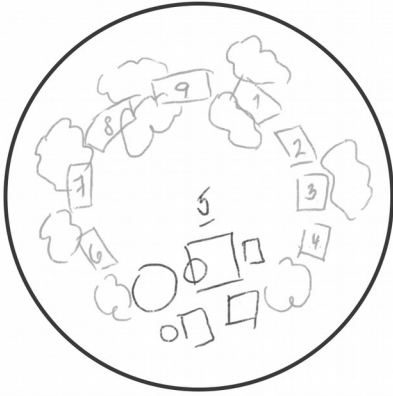
ACTION

The renaissance comes forward. This is the only scene with actual 3D objects - spheres, not just carboard cuts. Those spheres are representing planets, so they will orbit the Sun which will create a nice effect.

TIMING

1:14 - 1:24

ACTION

The renaissance is replaced with the classic and baroque period. As the timeline turns, the first scene is disappearing in the distance in the back.

TIMING

1:24 - 1:33

ACTION

When the classic and baroque scene ends the timeline turns again and the industrial 19th century comes. The second scene is now disappearing in the back. People won't see it, but they will notice that the scenes are not coming back to their field of view when the timeline turns next time.

TIMING

1:33 - 1:42

Figure 25: *Storyboard, page 3*

26

ACTION

The period of the world wars comes.

TIMING

1:42 - 1:56
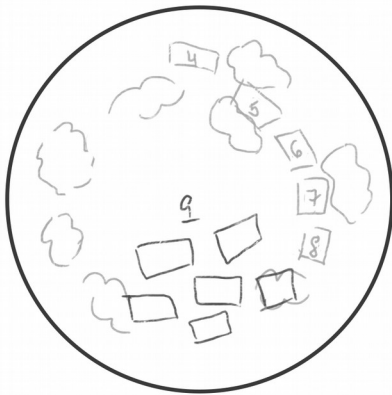
ACTION

The music calms down, the figures from nowadays fly to the center one by one, slowly, following the music.

TIMING

1:56 - 2:10
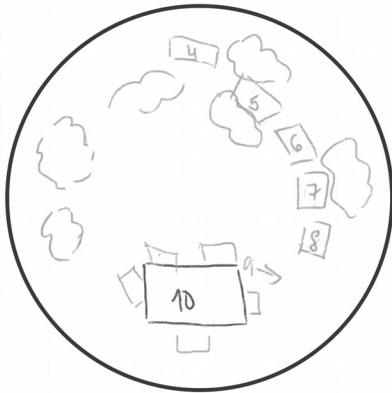
ACTION

The figures start to fly back to the timeline but on their way they reveal another figure that wasn't there before. It's a picture of a monkey from The Space Odyssey. The monkey is holding a bone, realizing it's a weapon.

TIMING

2:10 - 2:15

Figure 26: *Storyboard, page 4*
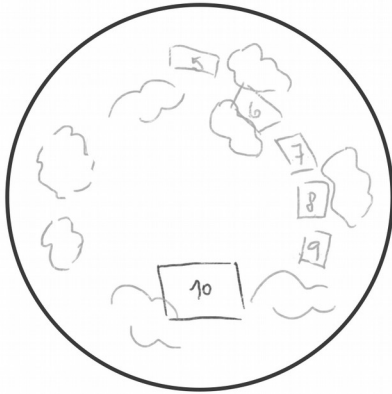
ACTION

The timeline turns for the last time, leaving the figure of the monkey on it's own, implying that this could be the next period.

TIMING

2:15 - 2:20

ACTION

The monkey flies back to the timeline as the music slows down and when it stops, the monkey is a part of the timeline and everything stays still again.

TIMING

2:20 - 2:29

Figure 27: *Storyboard, page 5*

Chapter two: 3D modeling in Autodesk Maya 2012

From all the 3D softwares available on the market I chose *Autodesk Maya 2012*. It is one of the most powerful and complex tools in the world of 3D and the film industry uses it a lot. I needed a powerful tool because I was going to create a film in a very unusual format, using a special camera that I knew Maya offered. But let me start from the beginning.

Modeling a planetarium

When setting up the scene for a spherical film, you have to realize that not all domes and planetaria look the same. Some of them are tilted, some of them not.
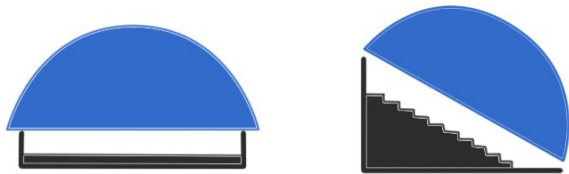
Figure 28: *Right - Upright dome, Left - Tilted dome*

As you can see in Figure 28, the main focus in a tilted dome is higher than in a regular planetarium. I was lucky enough to be able to test my film in both of them and see how different in real life the projection looks. For me it was easier to set up the upright scene because of the world coordinate system. It is easier to move and rotate objects when the y axis of the coordinate system matches the vertical axis of the dome. But I needed my film to work for both so I decided to combine those two domes in my scene. I started with modeling the tilted dome, taking the

parameters from the WorldWide Telescope [22].

Figure 29: *Planetarium with a tilted dome*

In Figure 29 you see what a planetarium with the tilted dome looks like. The most important parameter for me was the angle of the tilt, which is 20°, see Figure 30.
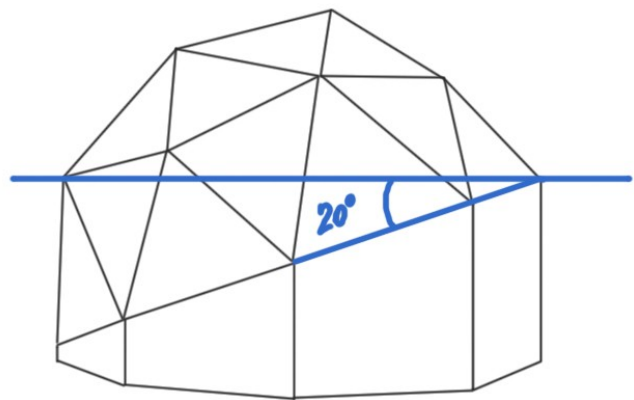
Figure 30: *Reference picture of the tilted dome*

Figure 30 is a sketch of the planetarium with

measurements, which I used as a reference picture when modeling the dome in Maya. I created the dome by cutting a regular sphere in half and the drum (walls supporting a dome) was made by extruding the edges of the hemisphere down to the ground. See Figure 31.
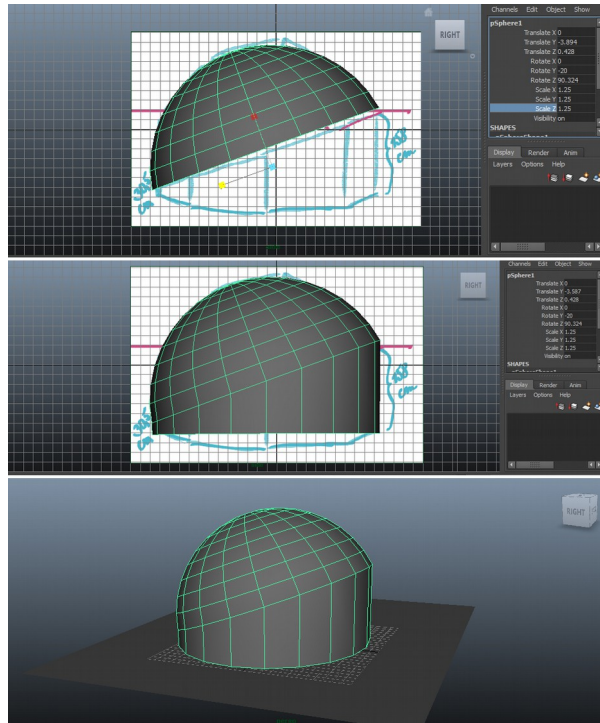
Figure 31: Modeling the planetarium

This model of the planetarium was supposed to be a guide, not one the models in the final scene. But I needed another dome to represent the actual sky dome where my film was placed. I created a new, larger hemisphere and matched the tilt with the planetarium's dome, see Figure 32.
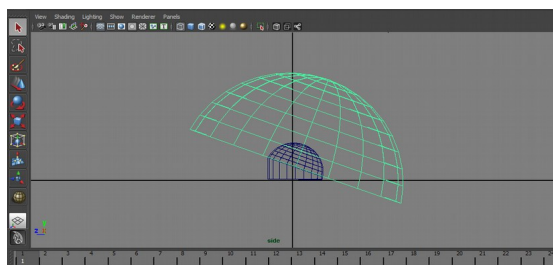
Figure 32: Modeling the sky dome

The sky dome was larger than the planetarium because I wanted to make some space between the two of them for my objects to move. Considering that zoom in or zoom out does not really exist in a spherical projection with a still central camera, I realized that the only way to simulate those camera movements was to move the objects back and forth instead and I needed space for that.

After modeling the planetarium with the tilted dome and the sky dome, I rotated the whole system to straighten it up and simulate the upright dome. This way I was able to set up my objects and animate them easier because the y axis of the world coordinate system matched the upright axis of the dome but I was always able to evaluate the scene from the point of view of the audience sitting in the planetarium with the tilted dome. See Figure 33.
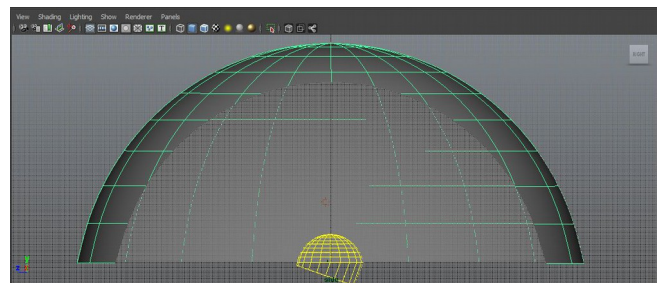
Figure 33: Mixed upright and tilted dome

Modeling a cardboard cut

There are about 50 objects in my film and I did not want to model them realistically for two reasons. It would take me a year to create them and it would not be dreamy at all. And my film was a dream. So I came up with a very effective way to stylize my objects and make the modeling easier. I decided to turn them into cardboard cuts and here is an easy way how to model such thing.

I used a reference picture in the frontal view and then traced the outline of the object with the *Create polygon* tool, see Figure 34.
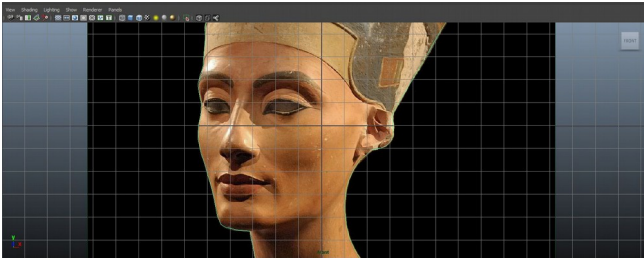
Figure 34: *Using the Create polygon tool in Maya*

As a result I had a flat polygonal face and I extruded it to make it a 3D object.
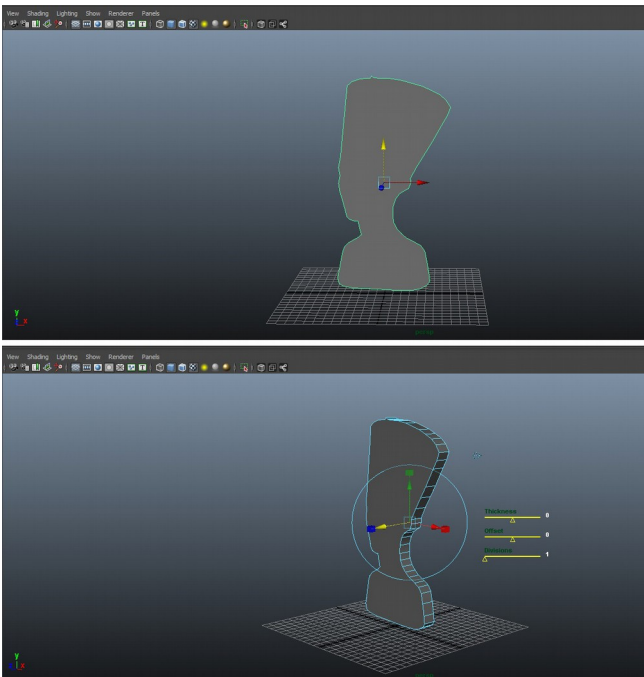
Figure 35: *Extruding a flat polygonal face*

To create a little variety among the cardboard cuts I made a few objects differently. For some of those representing a paper sheet or a canvas of a painting, I did not extrude the face, I left it flat but I curved it to simulate a real thin paper, Figure 36.

For objects that did not have a solid shape or were representing more than one object, such as Napoleonic wars or crusades, I also used just a flat face but I alternated the textures in Photoshop to mask the background and then applied an alpha channel in Maya. The final result was a flat picture but it was fading into transparency. See Figure 37.
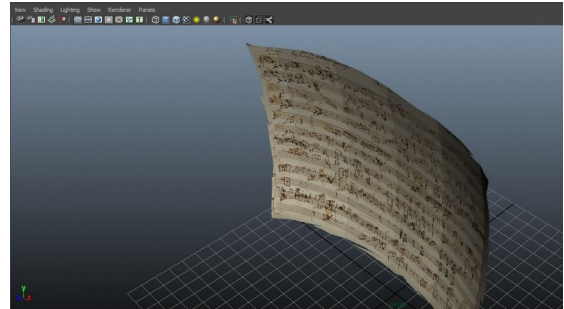
Figure 36: *Model of a paper sheet*
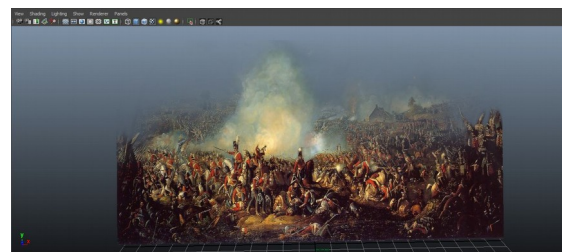
Figure 37: *Model with an alpha channel*

For the objects of planets in our Solar system I used actual 3D models. They were regular spheres with an applied texture and I was happy with the way it looked between all the cardboard cuts.
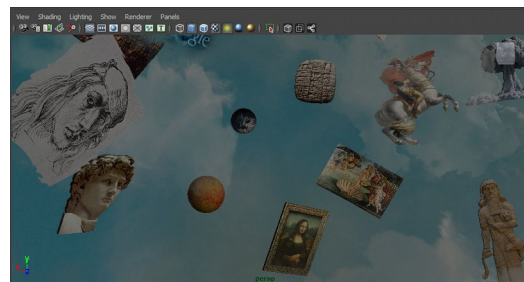
Figure 38: *Planet models among the cardboard cuts*

31

I also created 3D subtitles. Maya offers a *Text tool* which makes it really easy, so it can not be called a real modeling.
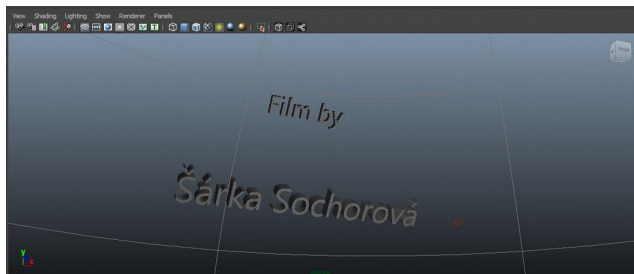
Figure 39: *3D subtitles*

Lighting & Materials

When it comes to using lights, materials and textures, Maya makes things very easy for us but it is interesting to have a closer look at what is happening on the background. The program has to calculate the correct color for each pixel on the final rendered picture. The famous *Phong reflection model* tells us how to do it based on the parameters of the light source, the material of our object and the normals of each face. The light source is defined by its position/direction and its color/intensity. The material is defined by its color and shininess. According to Phong reflection model every light consists of three components: ambient light, diffuse light and specular light, see Figure 40. Each of these lights is defined by a three-component vector, which tells us the values from 0 to 1 of the RGB (red, green, blue) color of the light. In this color model a white is [1, 1, 1] and a black is [0, 0, 0]. This means that the white color contains the red, green and blue colors and by modifying the ratio between the RGB components we can create color shades [14].
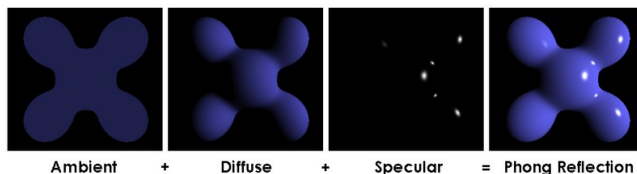
Figure 40: *Phong reflection model*

Ambient light is supposed to simulate the light reflected so many times by all the objects in the scene that nobody can tell its source, but the lighting is there, constant for the whole scene, brightening up a little bit even the darkest corners. In computer graphic it is very hard to calculate such light and it takes a lot of time, so the ambient light is used instead [14]. The vector for ambient lighting can look like this:

$$color\ _{ambient} = [0.1,\ 0.1,\ 0.1]$$

It is to make sure that none of the faces of our object in the scene is completely black because pure black looks artificial in most 3D scenes. The color of the reflected ambient light is calculated using this equation [5]:

$$ambient\ _{reflected} = ambient\ _{light} * ambient\ _{material}$$

As we can see it only depends on values that we set up manually: the ambient light color and the material ambient color.

Diffuse light is the most important component of light because it creates the 3D effect on an object. The diffuse light tells us the intensity of light that is reflected from the surface into all directions equally. It does not depend on the position of an observer but it depends on the position of the light source therefore on the angle of incidence. This means that the diffuse light changes when the objects or the light source move [4]. Here is an example of the vector for diffuse lighting:

32

$$color\ _{diffuse}=[0.0,\ 0.5,\ 0,5]$$

This diffuse light would have a sky blue color. It has no red in it and the blue and green components are only half intensity. However the color of the reflected light has to be calculated, here is an equation that tells us how [5]:

$$diffuse\ _{reflected} = cos\alpha * diffuse\ _{light} * diffuse\ _{material}$$

We can clearly see how the intensity of the reflected light depends on the angle of incidence. α is the angle between the normal of the surface and the normalized vector towards the light source, see Figure 41. Cosα is called a *diffuse coefficient* and it is a number between 0 and 1. It is equal to 1 when the light direction is perpendicular to the surface. That is when the diffuse light is the most intense.
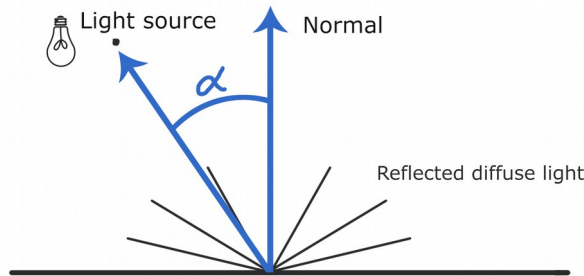
Figure 41: *Diffuse light*

Specular light creates the mirror reflections, for example reflections on water. It follows the law of reflection. The ray of light from the light source is reflected in a single outgoing direction. This light depends on the position of the light source and also on the position of the observer [14]. An example of a specular light vector:

$$color\ _{specular}=[0.2,\ 0.2,\ 0.2]$$

This light has a white color, all the RGB components have the same value so what this light affects is not the color of the object but its brightness. Again the color of the reflected specular light has to be calculated. Here is an equation for the *Blinn-Phong reflected specular light* [5]:

$$specular\ _{reflected} = cos\beta\ ^{material\_shininess} * specular\ _{light} * specular\ _{material}$$

This equation is a little more complicated. The final color of the reflected specular light depends on the position of the light source and on the position of the observer. The Blinn-Phong model uses a half vector S, which is calculated from the direction towards the light source and the direction towards the observer, see Figure 42. β is the angle between the half vector and the normal of the surface. Cosβ raised to the material shininess is a *specular coefficient.* It is also a number between 0 and 1 and it is equal to 1 when the light reflects directly into the eye of the observer [14].
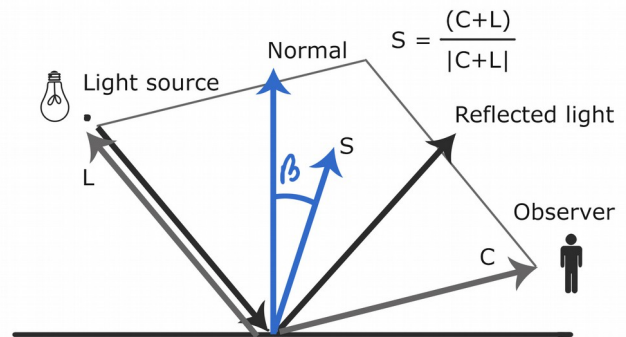
Figure 42: *Specular light*

Material of an object is defined by its color and shininess. The color has to be specified for each light component separately plus an emissive color, which is the color of the light that the object emits. So in the end we have four color vectors

and a shininess factor that define our material. The final color for a given point in the scene is then calculated by the following equation [5]:

$$color = emission + ambient\ _{reflected} + diffuse\ _{reflected} + specular\ _{reflected}$$

Where the values for each RGB component are calculated separately and clamped to <0.0, 1.0>. I simplified the whole process a lot but generally this is how light and material work together in computer graphics.
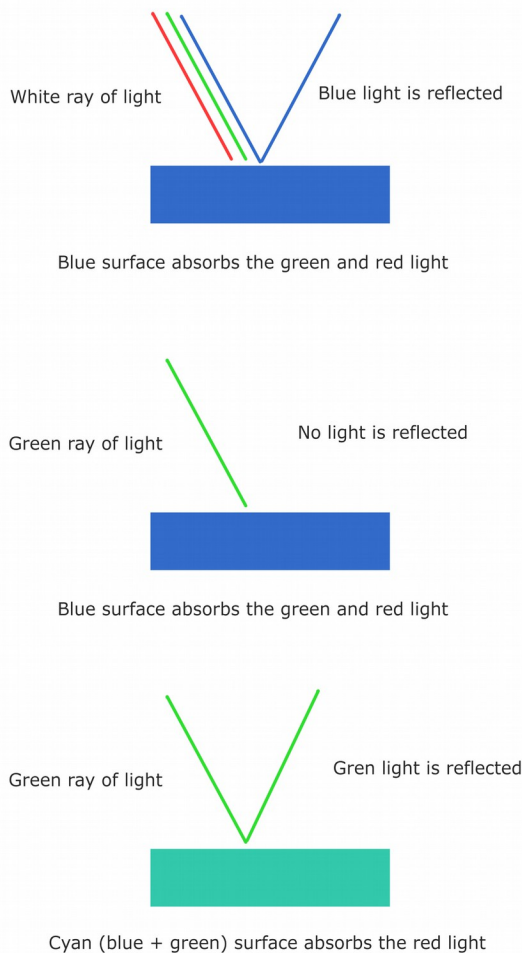
Figure 43: Material and lights in computer graphics

Figure 43 shows what it means practically. If we have a blue car, RGB [0.0, 0.0, 1.0], and we cast a green light on it, RGB [0.0, 1.0, 0.0], the car will appear black because it only reflects the blue light and absorbs the red and green light. And the green light does not have any blue color to be reflected. As you can see in all three equations calculating the reflected light, the light color and the material color are multiplied, separately for each RGB component, so if we calculate the final product of these two colors: [0.0, 0.0, 1.0] and [0.0, 1.0, 0.0], we get [0.0, 0.0, 0.0] which in the RGB color model is black. But if we had a cyan surface, RGB [0.0, 1.0, 1.0], and cast a green light again, the car would appear green, because the cyan surface only absorbs red light and reflects the blue and green light [4].

In Maya or any other 3D modeling software you do not have to worry about this. The materials and lights are pre-defined, so all you need to do is choose a type of light (directional light, point light, spot light) and a type of material (phong, lambert, blinn etc.) and then modify it according to your taste in a graphical user interface. I chose a point light, which simulates a classical light bulb that shines equally into all directions, and placed it in the middle of my skydome to make my scene equally bright. As for the material I chose the lambert material for all of my objects, its specular component is reduced, so the material does not shine and that is what I wanted for my cardboard cuts. The next step are textures.

Textures and UV mapping

Textures are a big help in realistic 3D modeling [6]. It can modify
- color

- reflected light from the environment (environmental mapping)
- normal vector (bump mapping, simulating little humps on a flat surface)
- geometry (displacement mapping, moving vertices in the direction of the normal)
- transparency using alpha channel
- hypertexture can help modeling complicated or unclear edges above the surface such as fire, grass or hair.

basic texture   environmental map

bump map   displacement map
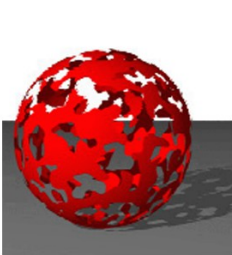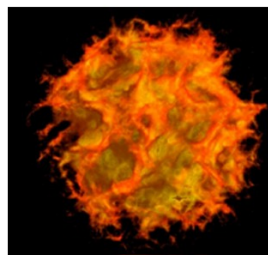
alpha channel   hypertexture

Figure 44: Usage of textures

But a texture has to be used properly otherwise the effect would be rather degrading. I will start with defining what a texture is. It is usually a 2D rectangular picture that we access using the UV coordinates. You can imagine it as the *x* and *y* axis. What you are doing when texturing an object is that to each vertex (defined by position coordinates x, y, z) of each polygon you assign the UV coordinates of your texture. It is called an inverse mapping because you are wrapping a 2D picture onto a 3D surface [6]. See Figure 45.
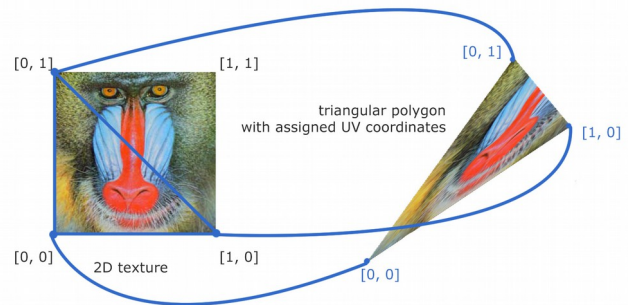
Figure 45: Assigning UV coordinates

In Maya there are two ways to create the UV coordinates. You can either choose one of the automatized tools that use a primitive object such a sphere, a cube or a cylinder as a reference or you can create the UV coordinates for your objects manually by cutting the objects into a specific UV net yourself. Maya provides a user friendly *UV Texture editor* where I did all my UV mapping.

First I selected the front and back faces of my object and created the UV outlines by projecting those faces from the x axis using the *Planar mapping* tool. This way I made sure that the shape of the outlines will be the same at the shape of my cardboard cut object. Then I selected the side faces and created their UV outlines by using the *Cylindrical mapping* tool. Figure 46 shows what the UV outlines of my object looked like.
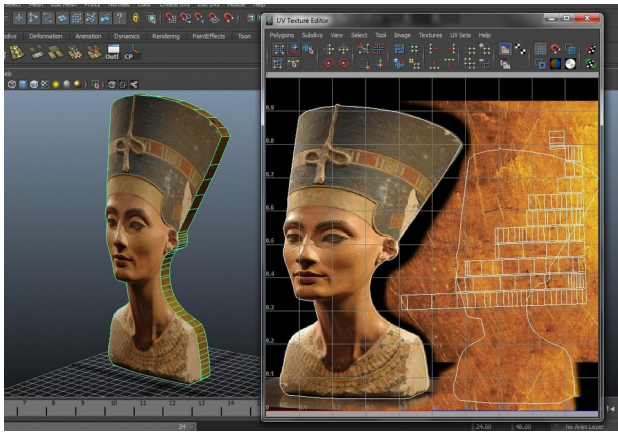
Figure 46: *UV Texture editor*

Then I assigned my texture that I had created in Photoshop before and adjusted the UV coordinates to fit to the picture.

During the whole process in the UV Texture editor you can watch your 3D objects in the scene and make sure that the texture fits as you planned.

For some of my objects I used a texture with an alpha channel to make the objects transparent at some places.
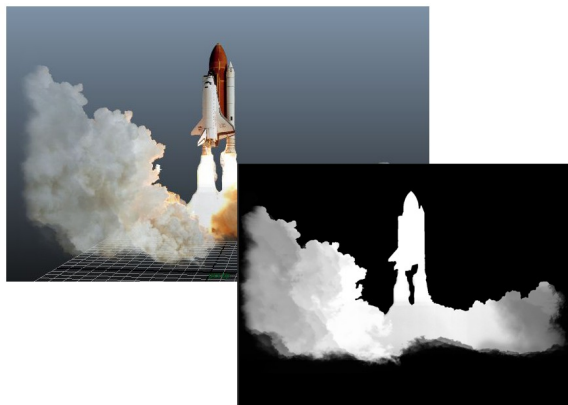
Figure 47: *Using alpha channel*

The process of mapping the texture is the same only you need to prepare a texture with an alpha mask and then save it in a format that preserves alpha channel such as .gif or .png. When you use this picture as a texture in Maya, it automatically

uses the alpha channel and makes your model transparent where the alpha is black, solid where the alpha is white and then adjusts the transparency according to the gray shades. Figure 47 shows a model with a transparent texture and its alpha mask.

Setting up the scene

After modeling and texturing all my objects I started setting up the scene according to my storyboard and realizing how different it is to make a spherical film from a regular cinema film. I made a few 2D animated films before and this was a whole new experience. Making a spherical film on a computer with a 2D screen means that you can never be sure what exactly will your audience see in the planetarium. It requires a lot of imagination and patience.

I started with importing all my objects into my scene and adding them into separate layers according to their time period. That way I could easily turn on and off the visibility of specific groups and keep an order in my scene.
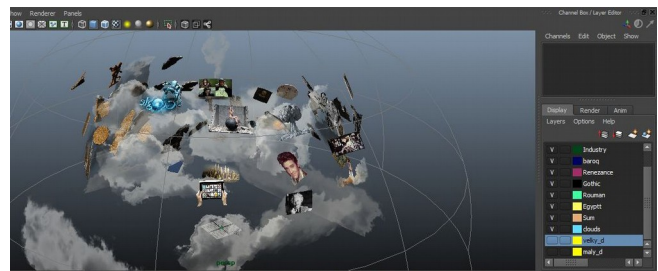
Figure 48: *Setting up the scene; layers*

Figure 48 shows the chaos on the scene with all the objects and the clouds. I had the domes turned off most of the time so that I could see from a better perspective the positions of all my objects. It is important to realize where is the audience try

to look at the scene from their point of view. So I set a regular camera in the center and tried looking at my scene to figure out the best composition of the objects. They needed to have the right position and tilt, they could not be upright, they had to face down to the audience and follow the curvature of the dome otherwise they would be distorted after projected in a dome.
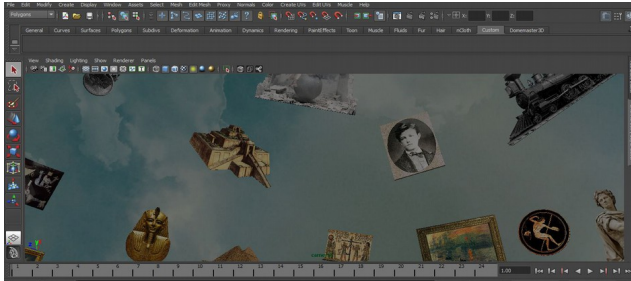
Figure 49: Setting up the scene; regular camera view

Figure 49 is a great illustration of the struggle with setting up a spherical scene. I did not see much of the scene and I could not move the camera back or further to see more because the camera was supposed to be in the center the whole time. If I moved it back I would not see the right angle of all the objects and the right angle was the most important thing. I was setting up a composition, making sure that none of my objects were overlapping others where I did not want them to. This was also the reason why I could not use any camera zoom. The scene was surrounding the audience, making them feel like they stand right in the middle of action. What happens in real life when you step forward to see something more closely? Everything that is behind you retreats. The real life scene is a solid unit, you do not have any zoom in or zoom out in there and a spherical film is much more realistic than a cinema film. It simulates scenes from real life therefore there is no zoom either. So since my camera was supposed to

stay still in the middle, whenever I wanted to simulate zoom I had to move the objects towards the camera. These are simple movements, but if you can not see your whole scene on the 2D screen of your laptop, it definitely is a challenge. I realized I was not able to set the proper composition using only my testing camera that by far did not cover all that I needed. It was time for me to set up the dome camera and start rendering the standard spherical format, the *domemaster* format. That was the only way to see the whole scene all together in one picture.

Figure 50 shows a few more images showing my attempts to capture the scene in the process of making.
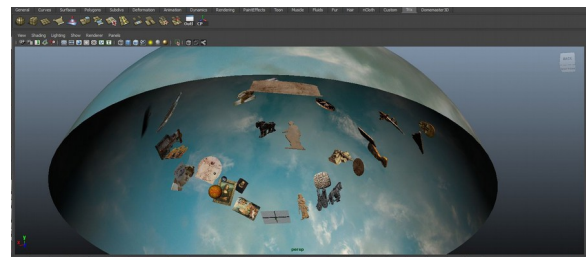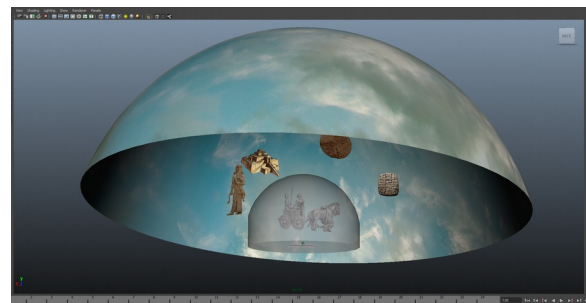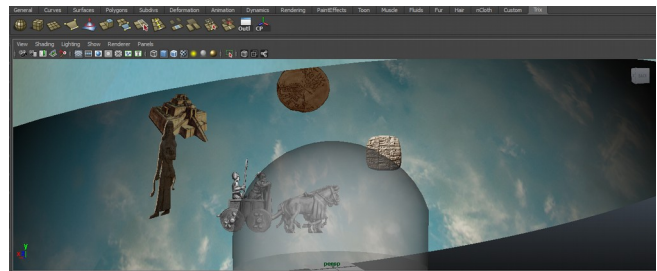
Figure 50: Setting up the scene

Chapter three: Rendering the domemaster

A domemaster format, also called a fisheye, is a circular image withing a square capturing all 360° around you but the tools to capture such field of view are not usually a part of 3D modeling softwares. There are, however, ways to get or create them. If you have enough time and patience you can construct a hemicube camera, if you want an easier way, there are plugins for 3D softwares with fisheye lens cameras to download or you can get a render engine with a built-in-fisheye, they are quickly becoming a standard [7].

Hemicube camera rig

If for some reason you can not use the fisheye camera, you can always create a hemicube camera rig. You have to set up 5 cameras into a specific arrangement. 4 of them are rotated -90, 0, 90 and 180 degrees around the y axis, the last one is rotated 90 degrees around the x axis, facing straight up. The focal length of all the cameras is 12,7. Horizontal and vertical film aperture is 1,0. If you produce renders from these cameras you will get a map of the hemispherical environment, a skybox without the bottom part [18]. These
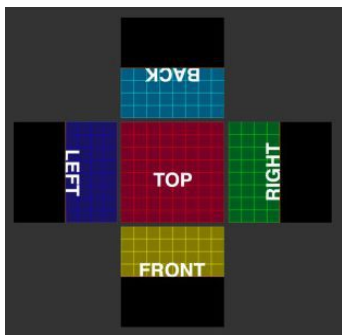
Figure 51: *Hemicube camera rig*

renders need to be stitched together into a domemaster. There are several stitching plugins for different softwares that you could use [16]:

- Adobe After Effects – *Navegar Fulldome, Sky-Skan DomeXF or Digistar Virtual Projectior.*
- Adobe Photoshop – *Domemaster Action Pack.*
- Nuke – *Spherical Transform Node.*

If you do not have of these softwares you can use one of the following stitching softwares [16]:

- *Glom* (Spitz)
- *PineappleWare Stitcher*
- *Cube2Dome by Paul Bourke*
- *Hugin – Panorama photo stitcher*

The following figure shows what a domemaster created from a cube map looks like.
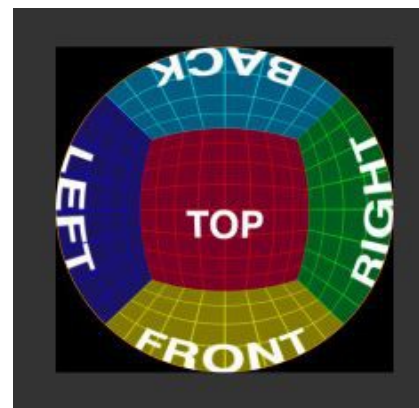
Figure 52: *Domemaster created from a cube map*

I decided not to use this technique unless

everything else goes wrong. It is too much work for something that can be created directly.

Domemaster plugins

There are lots of render engines that have fisheye support built into their framework and they are on the rise [7]. For instance:

- *Blender Cycles* (Blender Foundation)
- *VRay* (Chaos Group)
- *FinalRender* (Cebas)
- *Maxwell Render* (Next Limit Technologies)
- *RenderMan* (Pixar)

They provide the support within the camera attributes and cover all the famous 3D modeling softwares. But those renders are not for free so I chose to use one of the domemaster plugins that can add a fisheye lens shader into a render engine that does not have it built-in yet.

The most popular plugin is *Domemaster3D* (DomeAFL Stereoscopic) supporting both Autodesk Maya and Autodesk 3dsMax and it is free for download [7]. After installing and activating the plugin in Maya there is a whole new shelf with the domemaster tools.

Figure 53: Domemaster3D plugin

I used the FOV camera which covers 180° vertically and 360° horizontally – a regular hemisphere. I placed the camera in the center of my world coordinate system which was also the center of my scene. Figure 54 shows what the camera looks like. It has a guiding outlines of the hemisphere that it is capturing and the camera is facing straight up.
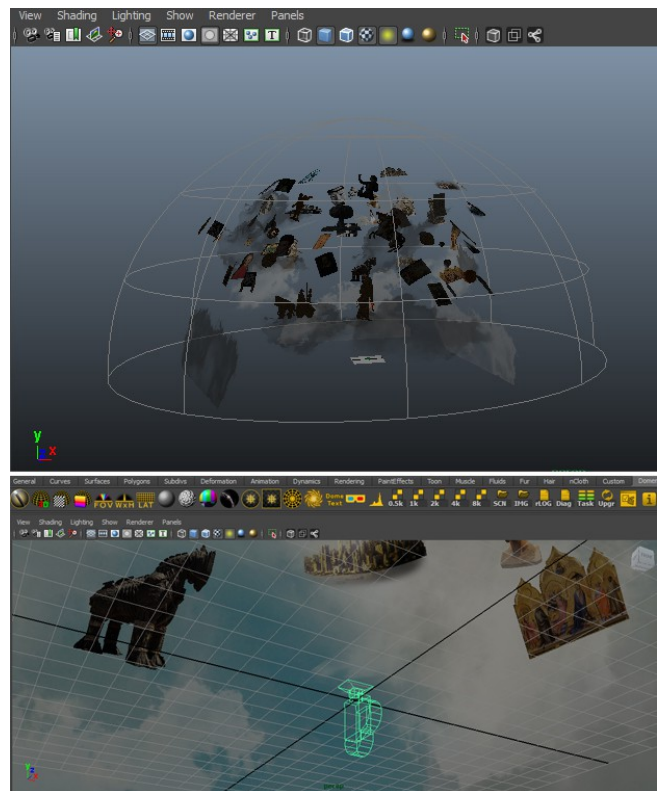
Figure 54: FOV camera

It was actually easier than I expected, searching for the right plugin and the right camera on the domemaster3D shelf took longer than the setup because that was all I had to do. I set the rendering settings to render 2K pictures and rendered my first domemaster.

Figure 55: My first fisheye render

39

I could finally finish setting up my scene. The fisheye renders offered enough visual information for me to see the composition clearly and get my scene ready to start animating.

Before I actually started with the animation, which is a long and complicated process, I went to a real dome theater to test my first domemaster renders. I had to make sure that the scene was working properly, that my renders looked like what I expected. The testing and projecting in a real dome theater and planetarium will be covered in more details in part three. For now I will only say that my first scene, of course, was not working. It was important for me to see the relation between a fisheye picture and what it looks like projected in a dome. I learned a lot from my first testing and rearranged my scene. Luckily the second testing went all right and I could start animating my film.

Figure 56: *The first frame of my film*

Chapter four: 3D Animation in Autodesk Maya

Maya offers a lot of layouts modifying the user interface to make it easier to work with for different operations. There is a layout for modeling, rendering, simulating dynamics and of course, one of the layouts is for animation. Animation in Maya is a classical key framing process. You pick an object, set the feature that you want to animate, select a specific frame on your timeline and set the key. It is a very simple process, yet it can get complicated in complex scenes. My scene has over 50 objects and I was going to animate translation, rotation, scale and texture transparency, so if I did not prepare my animation well, it could get disorganized very quickly. Luckily my scene circular architecture was potentially easy to animate. I had two main types of movement, one was turning the whole scene around the center of the dome, second was when a specific group of objects flew towards the camera and floated in the air for a couple of seconds, then came back to the timeline. So I had to prepare for three possible difficulties. Animating to the rhythm of my music, animating the pivot of the coordinate system and creating ease in, ease out animation.

Animating to music

The animation layout in Maya offers a timeline at the bottom of the scene. To set the length of your animation you have to enter the total number of frames and then move within your timeline using a slider that shows your timeline from a one given frame to another. This allows you to zoom in to a certain place and see it in more details or zoom out and check your timeline as a whole. There are also buttons to operate the playback.

Before I could start animating I had to set the frame rate and the length of my film. I set the recommended frame rate for spherical films which is 30fps. It is higher than the classical film frame rate 24fps because spherical films are projections for large screens in planetaria and on a screen this big, every movement is magnified so it is better to have a higher frame rate which smoothens the transitions. As for the number of frames I simply multiplied the seconds in my music track by my frame rate.

$$149*30=4470$$

I rounded the number off to 4500 and I was ready to start.

If I were creating a traditional 2D cartoon, animating to music would be a very complicated process. I would have to analyze the music track much more carefully and calculate numbers of all the frames that needed a specific change of movement, then adjust the animation to fit in those pre-calculated frames. Luckily this was not the case because Maya has the option to import music to the timeline, therefore you can check at any given time if your animation fits the rhythm. It also shows the waveform, so you have the visual of what the music looks like.
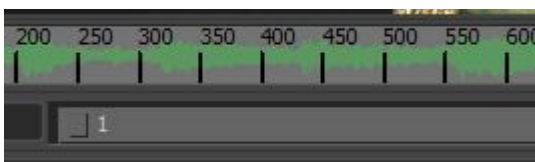
Figure 57: Animation timeline with sound

As I mentioned earlier, one of the steps in a key framing process is to set a specific frame where you want your change to happen. Of course I had the tentative timing prepared in my storyboard but it was not until now that I had to choose specific frames. Importing music to the timeline made this step very easy because I did not have to calculate those frames manually.

Animating the pivot

Every 3D model is created in the model coordinate system. Which means that the center of the coordinate system, the pivot, is in the center of the object. This makes local transformations such as translation, rotation and scale, easy because it feels natural. When you rotate the object, it rotates on the spot around its own axis. when you scale it, it scales equally in the scaling direction. Technically I had no problem animating the parts where a specific group of objects flies towards the camera and floats in the air. I animated each model separately in its model coordinates and the only tricky thing was adjusting the tilt and the composition to fit the spherical architecture. I had to take a lot of testing fisheye renders to make sure that the scaling and positioning were all right.

The parts where the whole scene rotates around its center could be very easy but I had to find out how to switch from the model coordinate system to the world coordinate system. At this point I did not want to rotate the objects around

their own axis, I wanted to rotate all of them at once around the dome vertical axis which matched the y axis of the world coordinate system, refer to Figure 58. This switch is possible in the *Rotation tool* settings, however it is not keyable and it does not act as I expected. It only straightens the coordinate system axis but it does not move the pivot. So I figured I had to simulate this coordinate system change by moving and animating the pivot.
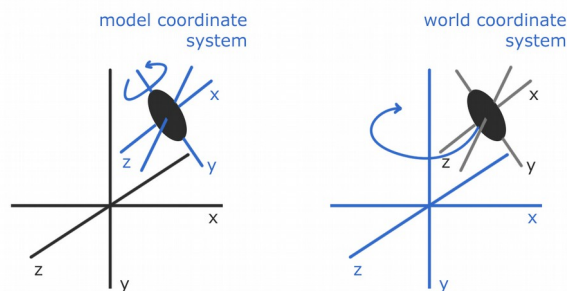
Figure 58: Model and world coordinate system

Chanel Box / Layer Editor show the active keyable elements and by default you can keyframe the translation, rotation, scale and set the visibility to on or off. To set a key you either press the 's' key which sets the key to all the elements in the Chanel Box, or you can click the right mouse button on a specific element and choose 'Set key' for it separately. In order to keyframe the pivot you have to open the *Channel control* window which shows all the keyable elements for a model and then pick the *Rotate Pivot Translate* for the x, y and z axis and send it to the Chanel Box/Layer Editor. This element changes when you move the pivot while the Rotation tool is on. The pivot can be moved by pressing the 'd' key and then dragging the mouse wherever you want your pivot to be. If you press the 'd' and the 'v' key simultaneously, it snaps the pivot to the grid, so it is easier to get it right to the center of the world

coordinate system.

Figures 59 and 60 show the process of moving the pivot for all the models at once. I selected all my models, turned the Rotation tool on and pressed the 'd' key. Figure 59 shows the pivots of all my models being at their centers. Then I pressed the 'v' key and dragged my mouse to the center. All the pivots snapped together as shown in Figure 60. Having all the pivots in the center I was able to rotate the whole scene around its center very easily.
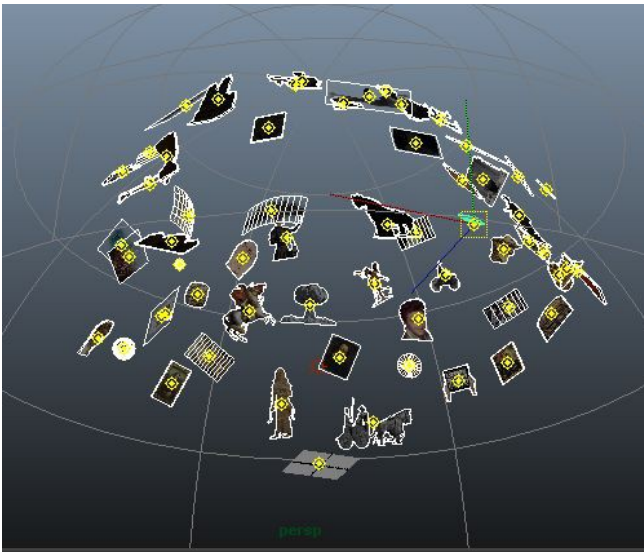
Figure 59: *Pivots of all the models*

Figure 60: *Pivots after being moved to the center*

The pivot movements had to be keyframed because for presenting each era I needed the pivots to be back at their models' centers to be able to move, rotate and scale the models properly.

Ease in / Ease out

To make your animation look more natural, you need to change the dynamics of the movement. It simulates the real life, when you drop a ball on the floor, it speeds up on its way down and slows down on its way back up. To change the dynamics of your movement in Maya you need the *Graph Editor.* The Graph Editor sets the key frames in time and shows the distance, angle, scale – time graph of your animation and you can adjust the curve.

In Figure 61 I set two keyframes animating a rotation around the y axis of a sphere. One keyframe is on the first frame, where the rotation is 0, the second keyframe is on the 24th frame where the rotation is 70 degrees. The graph shows those two keyframes in time and you can see a classical linear function. The speed of this movement is constant.
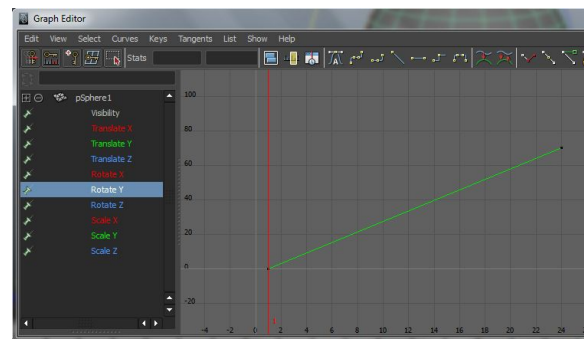
Figure 61: *Graph Editor – linear movement*

Ease in means that the speed at the beginning of the movement is a little slower and then it speeds up and finishes at full speed. To

achieve that change of dynamics you have to change the curve by adjusting the tangents to this:
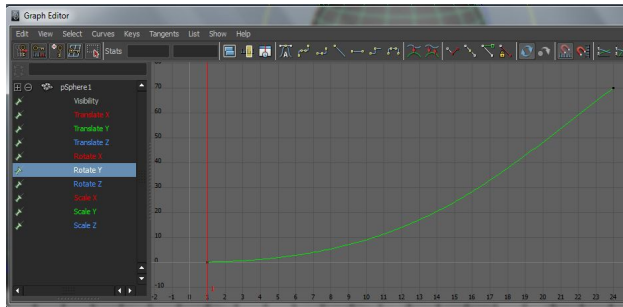
Figure 62: *Graph Editor - Ease in*

Ease out starts at full speed and then slowers down in the end. Figure 63 show what the curve looks like.

The mixture of those two dynamics is called *Ease In/Out* and the movement starts slow, speeds up to the full speed and then slows down in the end. The curve of this dynamics is shown in Figure 64 and this was the type that I used for all my movements because it looks the most natural.
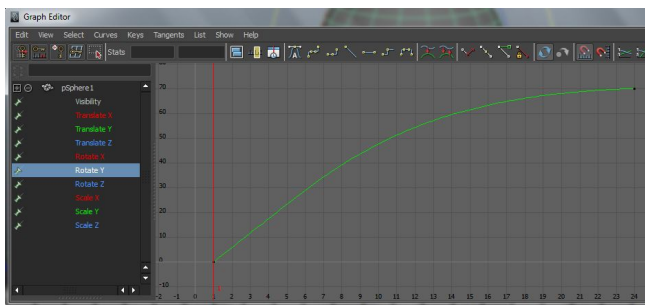
Figure 63: *Graph Editor - Ease out*
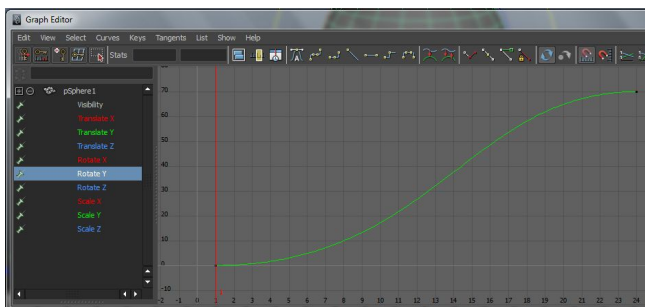
Figure 64: *Graph Editor - Ease In/Out*

Animating subtitles

I made the subtitles in a separate file, changed the dome material color to black and removed the texture from it. The text of the subtitles had a white material and no texture either. I made the animation simple, I could have just animated the material transparency to simulate fading out and in to the black but I wanted the subtitles to move towards the audience to enhance the 3D effect. It was a very slow and subtle animation, the subtitles started in the distance where they fade in from the black, flew to the front, scaled up and then faded out when another text replaced them in the distance.

The material transparency is not a feature of a model and as such can not be displayed in the Channel Box/Layer Editor like transitions. It is a feature of a material, which can be used on multiple objects. To keyframe this element you have to go to the *Hypershade Editor* that stores all the materials and then double click on the material that you want to keyframe. It will appear in the *Attribute Editor* with all its features such as transparency. Then you can set the transparency from 0 to 100, click the right mouse button and select 'Set key'.
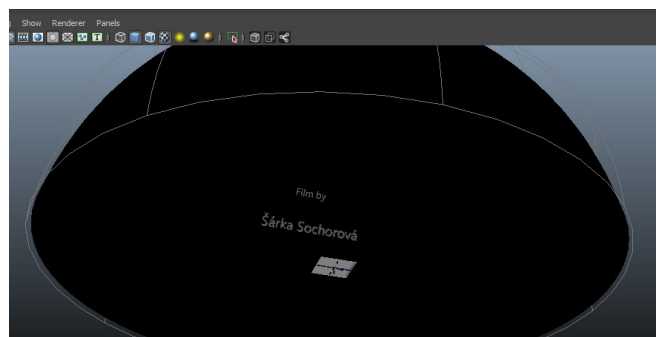
Figure 65: *Subtitles*

This is how I animated my film, technically it was not difficult, it was more

challenging on the artistic side, having to come up with the movements and the story and mostly keeping the composition together. Whenever I set a new keyframe I would render the fisheye picture to make sure everything looked correct. And even then I could not be absolutely sure that it would look correct in the planetarium. Only projecting in a real planetarium or a dome theater would show.

Chapter five: Rendering and Postproduction

Rendering requirements for spherical projections are 4K resolution and the frame rate at least 30 frames per second, sometimes it is recommended to have 60 frames per second for smoother projection [19]. I rendered my film in 2K resolution for testing purposes to save time. Rendering such high resolution footage counts to days. It took me four days to render my film in 2K and the quality in the planetarium was a little lower but for my testing purposes it was enough. However if I was to render my film for a real projection I would definitely have to render my film in 4K to achieve required quality.

Rendering in Maya

For rendering my footage I used the *Mental Ray* render engine that Maya offers. I could choose between rendering a png sequence and an avi video. I decided for the png sequence for many reasons. One of them was the quality loss. I had my film and my subtitles in two separate files so in the end I would have to put those two avi videos together in another software and render them again. Another reason was that I wanted to add about 5 seconds of a black screen at the beginning and in the end because a movie should not start right away, there has to be some time for people to adjust. The main reason was a possible crush of the system and loosing lots of rendered work. If you are rendering a video and the system crushes in the middle of the process, you loose everything and you have to render it again from the start. However if you are rendering a png sequence, you never loose those pictures that are already rendered. You can also run the render at multiple computers, dividing the work into pieces. This is not a big issue if you are rendering a small video that takes an hour to render. But my film was going to take days. I had 4500 frames of film footage and 625 frames of subtitles footage. My rendering resolution was 2K with 300 dpi and it took 4 days to render. I could not risk having my computer crash on the 4th day and loosing all my rendered footage. So I rendered a png sequence. You do that in the *File Output* render settings by selecting an extension pattern that has a '#' symbol in it such as *name#.ext*. The '#' symbol stands for a number that will be assigned to each frame. Then you set the image format to 'png' and insert your required resolution and dpi. Mental Ray offers a lot more features such as *Global Illumination, Ambient Occlusion, Caustics, Ray Tracing* and other algorithms that help to add more realistic lighting to the scene but they are also computationally much more expensive and consequently much slower to generate. I was happy with the way my scene looked, it was not meant to be realistic in the first place and all the action happened in the sky among the clouds with no walls, ceiling or floor to reflect the light so I did not need expensive algorithms calculating it for hours. However for common scenes of a room with furniture, these algorithms work wonders and it is definitely worth waiting for the result because the scene looks much more photorealistic.

After finishing the render settings you have to open the *Batch Render* window and click the *Batch Render* button.

Postproduction in Adobe After Effects CS6

Now that I had all 5125 frames of my film footage, I needed a postproduction software to bring it all together and create my final movie. I was lucky that Union College where I am currently studying owns licensed version of the whole Adobe Suite CS6 pack and I could use *Adobe After Effects* for my postproduction.

I created a new composition, setting the resolution to 2000 * 2000 pixels, the frame rate to 30fps, the duration to 3 minutes and 15 seconds and the background color to black. Then I imported my music track, both of my png sequences and also the first frame separately. It is always good to stay on the first frame for a little while before the animation starts so that people can orient themselves. Beginner filmmakers often do not realize it because they watch their video over and over hundreds of times and it seems all clear to them. But when people see it for the first time, they need a while to adjust and focus. If they came to the planetarium and my film started right away they would miss half of it. That is why I wanted to add 5 seconds of a black screen at the beginning and then keeping the first frame for about 3 seconds before actually playing the sequence. So I put the picture of the first frame on the 5th second, keyframing the opacity to create a fade in effect. The effect took about 1 second so in the end the first frame rested on the screen for two seconds and then my film and the music started.

I would put the last frame on rest in the end too but I did not have to do that because I added about 35 extra frames to the end of the animation already in Maya and also the ending of the movie is slow enough so there was no need to extend it. I keyframed the opacity at the end of the footage to make the video fade out to black again before the subtitles started.

Figure 66: *Adobe After Effects project*

Figure 66 shows the structure of my project in After Effects. Everything was ready for rendering the final fisheye movie. I chose the H.264 output format for the video and 48,000 kHz stereo audio. The final movie has 3:14 minutes, 2K resolution, named *time.mp4* and it is included in the enclosed DVD.

Part III: Spherical projection

Chapter one: Warping

Both domes that I tested my film in, the VOŚ and SŠSE, Novovysočanská in Prague and the Suits-Bueche Planetarium in MiSci Museum, Schenectady, use Paul Bourke's spherical mirror for projection. That technique requires a special warped image made out of the fisheye format.
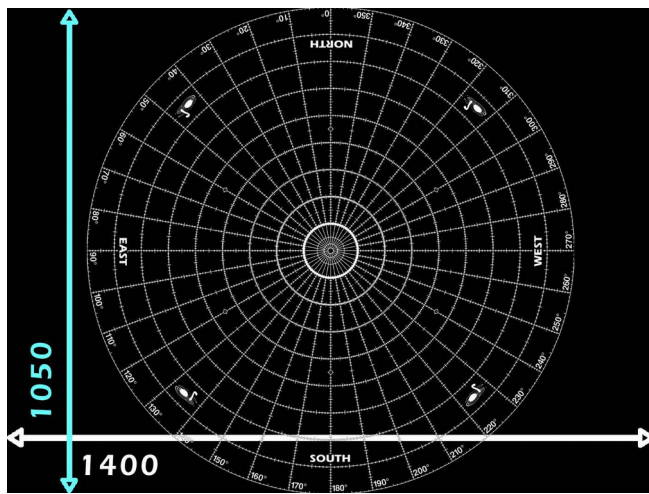
Figure 67: Fisheye grid
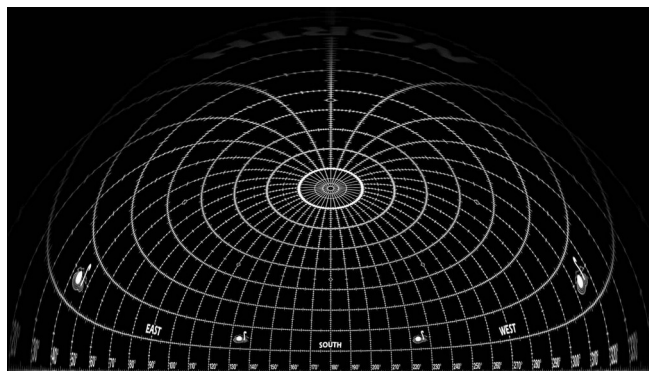
Figure 68: Warped fisheye grip for a spherical mirror projection

Figure 67 shows a classical fisheye format image, Figure 68 shows the same image warped into the format for the spherical mirror. Both of these images will look the same when projected in a dome. The first one will be projected by a fisheye projector while the warped one will be projected using the mirror. This grid is an ideal testing pattern for spherical projections using the mirror. If the projection is correct the "north pole" of the grid should appear on the top center of the dome. The parallels and meridians should appear horizontal and vertical and 0th parallel should line the bottom edge of the dome.

In order to create the warped image for a specific dome, projector and mirror correctly, you have to map the points from the projector frustum on the dome surface points. This is clearly a 3D matter but it can be turned into a 2D problem by translating the geometry withing the dome. You have to move the mirror into the center of the dome and rotate it so that the point on the projector frustum, the point on the mirror and the point on the dome surface are in a single plane [1].
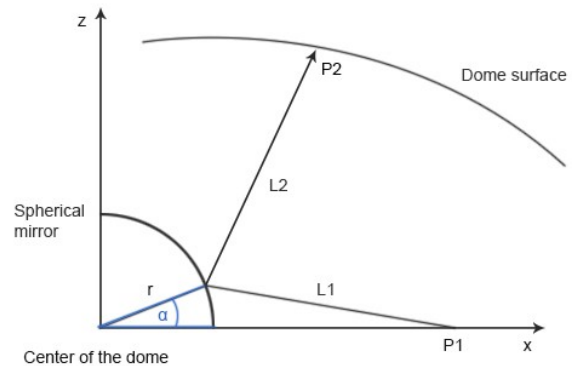
Figure 69: The geometry within a dome

Figure 69 shows the translated geometry in

a dome. The projector is placed in P_1, the mirror is of radius r and the projected point on a dome is in P_2. The light path from the projector to the mirror is L_1 and the light path from the mirror to the dome surface is L_2. In order to establish relationship between positions in the projection plane and the dome, the angle α has to be found. Below is an equation for L_1, refer to Figure 70:
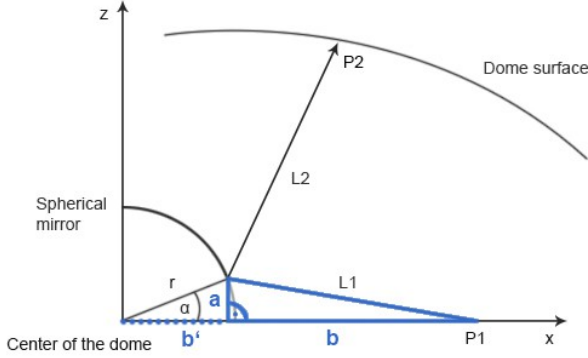
Figure 70: *The relationship between positions in the dome; solving for L_1*

$$L_1^2 = a^2 + b^2$$

$$sin(\alpha) = \frac{a}{r} \quad \rightarrow \quad a = sin(\alpha)*r$$

$$b = P_1 x - b'$$

$$cos(\alpha) = \frac{b'}{r} \quad \rightarrow \quad b' = cos(\alpha)*r$$

$$L_1^2 = (sin(\alpha)*r)^2 + (P_1 x - cos(\alpha)*r)^2$$

Equation for L_2, refer to Figure 71:

$$L_2^2 = a^2 + b^2$$

$$c = P_2 z - c'$$

$$sin(\alpha) = \frac{c'}{r} \quad \rightarrow \quad c' = sin(\alpha)*r$$

$$c = P_2 z - sin(\alpha)*r$$

$$d = P_2 x - d'$$

$$cos(\alpha) = \frac{d'}{r} \quad \rightarrow \quad d' = cos(\alpha)*r$$

$$d = P_2 x - cos(\alpha)*r$$

$$L_2^2 = (P_2 z - sin(\alpha)*r)^2 + (P_2 x - cos(\alpha)*r)^2$$
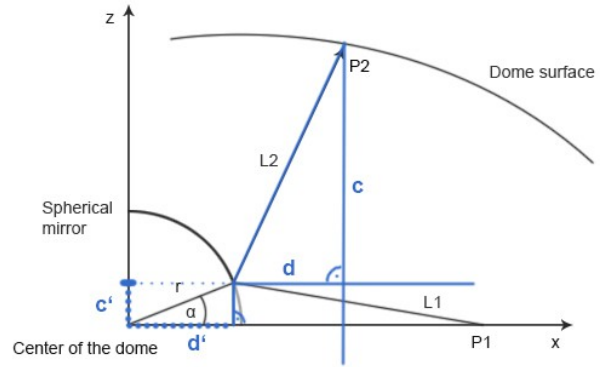
Figure 71: *The relationship between positions in the dome; solving for L_2*

According to the Fermat's theorem that light travels by the shortest route you can find the angle α by minimizing the path of the light from the projector to the dome surface [1]. You are looking for an α that minimizes

$$\sqrt{(L_1^2 + L_2^2)}$$

After establishing the positions in the projection plan, a *regular mesh* can be created. Each node of the mesh is represented by normalized coordinates of the projection frustum (x, y), normalized coordinates of the fisheye image (u, v) and the intensity value. Intensity can compensate the brightness differences caused by various lengths of paths from the projector to the dome surface. The process of warping the fisheye images vary depending on the position of the mirror, the projector and on the optical characteristics of the projector. The data of the warping mesh are stored

50

in a file called a mesh map which is required by warping softwares. That way the same content can be projected in theaters with different architectures [1].

Paul Bourke himself wrote the only two warping softwares for Windows that exist so far. Apple users have it easier because Paul Bourke's MacOS-X movie-player application *WarpPlayer* can do the warping "on-the-fly". I was using a PC the whole time so I needed his Windows products. One of them, the *IMGWarper*, creates pre-warped image frames that can be later put together in a conventional video editing software. The other one is a plugin for the VLC player, *VLCWarper*, and it warpes videos in real time.

IMGWarper for Windows

This UNIX based application was derived from the original Paul Bourke's *TGAWARP* for MacOS-X. Richard S. Wright Jr. of Software Bisque compiled a Windows binary from the source code and the result is an application that runs on Windows and warps images of TGA, JPG and PNG format. It does not create videos, it makes frame sequences. It does not have any graphic user interface, it is a command-line style application. You point it to a numbered fisheye picture sequence, it runs through it and outputs warped images with a "w_" preposition in the filename [8]. In Figure 72 you can see an example of usage of the IMGWarper. The example along with additional information is provided by the Loch Ness Productions who also sell the product on their website. I only used this software to warp a few testing frames, my supervisor owns this warper, so he did it for me, which I am thankful for, but it takes a lot of time, so for warping my final film I used the VLC plugin, which does not

pre-warp images and runs is real time.

```
Example 1: tgawarper -w 1024 frames%d.tga
              xyuv.map

    Expects frames called frame0.tga,
    frame1.tga,... etc. in the current directory.
    Will create output files called w_frame0.tga,
    w_frame1.tga,... etc. in the current directo
    ry.
    The frames will be 1024 pixels wide with 2x2
    antialiasing.
    The map file "xyuv.map" is expected in the
    current directory.
```

Figure 72: *IMGWarper, example of use*

VLCWarper

This special feature running on the VLC Player platform is the only Windows application that warps fisheye videos in real time and needs no pre-warping. It actually is not a real plug-in. The VLCWarper is hard-wired into the source of VLC itself, version 2.1.1, code-named Rincewind. So it is recommended not to update your VLC player because the future releases would overwrite the warp-capable version [21].

After installing the warper a new tab appears in the preferences. It is the Warp one and it requires loading a mesh map. Another thing that needs to be changed before playing you warped movie is the video output settings. VLCWarper uses OpenGL to do the warping so the video output needs to be changed from *Automatic* to *OpenGL video output*. Then you can open a video of almost any movie format such as MPG, MOV, WMV, M2V, MP4, and lots more, turn to full screen and watch the fisheye footage change into the warped video [21]. I used this software for the final testing of my film because it is much easier and faster than using the IMGWarper. I used the included mesh map for the 16:10 resolution. Here is what the video looks like in the VLCWarper:

Figure 73: *Playing my film in the VLCWarper*

Chapter two: Dome Theater in Prague

I did my first testing in the theater dome in the High and Vocational School of Low-current Electrical Engineering in Prague, Novovysočanská street. Their dome theater was built according to the construction plan from WorldWide Telescope [22].

Figure 74: Dome Theater, WorldWide Telescope

They use Paul Bourke's spherical mirror system with a F10 AS3D Projector. The spherical mirror and the projector are located by the back side of the theater, leaving the center space free for audience. The dome is tilted and has 3.5 meters in diameter and the whole inside of the theater is really small, so it was difficult to take illustrating pictures of my film.

In Figure 75 there is a picture of the inside of the dome theater in the school in Prague. The projector is facing the back side where the spherical mirror is set and I projected a calibration grid on the dome.

Figure 75: The Dome Theater in Prague

It was the first dome I saw my first fisheye renders projected in and I, of course, found out that my first fisheye renders were not good. Before I started animating, I created a testing scene and made a few fisheye images to project them in the dome. Figure 76 shows the fisheye render, Figure 77 shows the same image warped for spherical projection using the IMGWarper for Windows and Figure 78 and 79 show that warped image projected in the dome theater.

Figure 76: Fisheye render, testing scene

Figure 77: Warped image of my scene

Figure 78: Front part of the dome with my scene projected
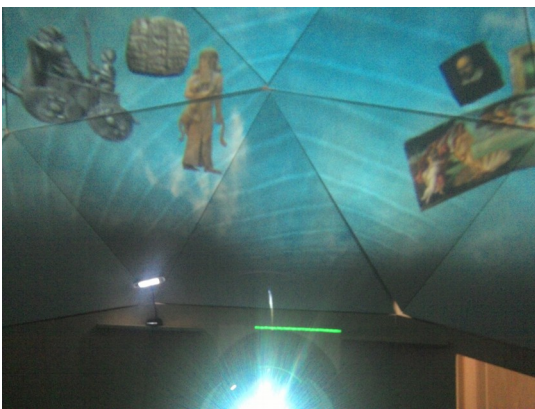
Figure 79: Back side of the dome with the spherical mirror

As you can see there is one huge problem that I did not see until I did the testing in a real dome. The fisheye render looked good to me but in the dome I realized that my objects were way too close to the edges of the fisheye. It caused that during the warping the frontal part got distorted because the edges were blended into black. Also because of the tilt of the dome all the action was happening too low, just above the floor, but when people are sitting in the center, their main focus is not above the floor, it is higher, almost at the "north pole" of the dome. I figured that there was a specific space in the fisheye image where the action should be happening which is shown in Figure 80.
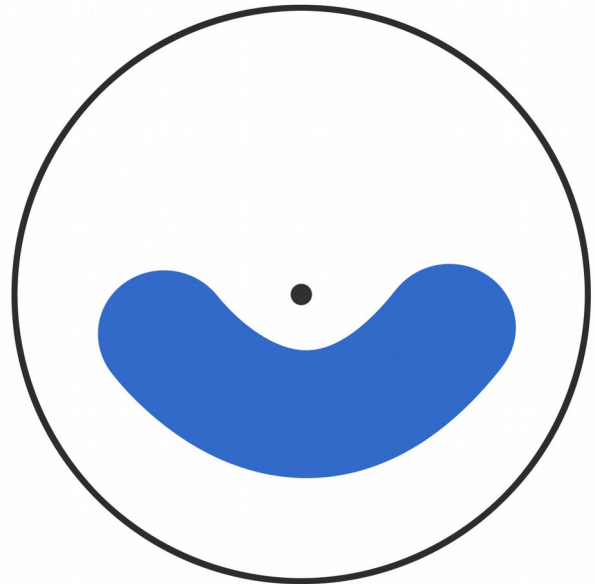
Figure 80: Fisheye space for action

Of course there is action happening in the back part too but people usually do not turn their heads 180° to the back. They can but the main focus is always in the front. And that applies for both, tilted and upright domes. Also the edges have to stay clear. I later found out that the mesh maps provided with the VLCWarper did a clean warping without blending the edges in the front to

54

black, but still it was important to focus the main action closer to the center of the fisheye because of the composition. In the dome, tilted or not, it does not look good if everything is happening just above the edges and the top stays empty. So when I started setting my real scene I made sure to take fisheye renders every time I moved an objects and check they fit in the pattern. Figure 81 shows what the testing fisheye image should look like.

Figure 81: Corrected fisheye of the testing scene

Chapter three: Projecting my film in the Suits-Bueche Planetarium in MiSci Museum, Schenectady, New York State

Short after my first testing in Prague I moved to Schenectady in New York state to attend an exchange study program at Union College. Which meant that I was no longer able to test my film in the dome theater in Prague. However Ms. Megan Norris from the Suits-Bueche Planetarium in MiSci Museum was kind enough to let me work on my project in their planetarium which I am very thankful for. Their planetarium is way bigger than the dome theater in Prague and since it is an actual planetarium there is no light leakage, so I could see the full colors of my film. The dome has 10 meters in diameter and it is upright. They also use the spherical mirror system but their projector GOTO Chronos is placed in the center, not in the back. That is probably the only disadvantage because the projector takes the best place from the audience. But other than that the conditions for projecting my film were way better than in the small dome theater.

I created the first frame of my film learning from my previous mistakes, so I made sure my scene was covering the right space in the fisheye image. Then I went to the planetarium to test it. I simply connected the projector to my laptop using the HDMI cable and played my movie in the VLCWarper using the 16:10 included mesh map. Figures 83, 84 and 85 show the fisheye image, warped image and a photo from the planetarium of the first frame of my film.

Figure 83: The first frame of my film
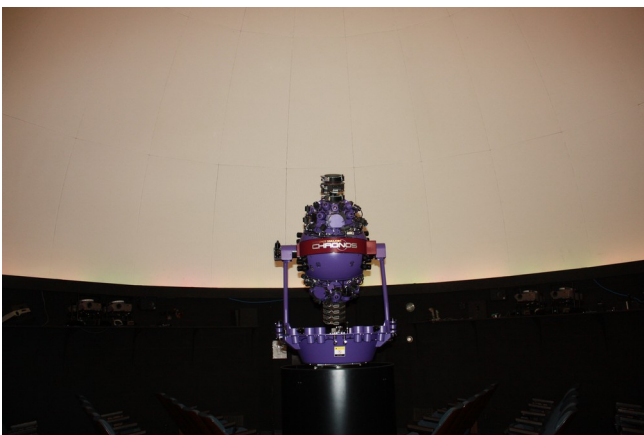
Figure 82: The Suits-Bueche Planetarium

Figure 84: The first frame warped

Figure 85: The first frame in the planetarium

Even though the planetarium was big, it was still difficult to document my projections because there is no way a 2D picture from a camera could cover the whole dome surface and show it all. Also it is dark in the planetarium but if the flesh on the camera is on, there is nothing captured on the screen, but without the flesh it is hard to take a sharp image.

This time the testing went all right. I found out that moving the objects away from the edges helped and the projection looked great. Also notice the difference in the warped image. The frame from my testing scene was warped using the IMGWarper for Windows with a custom made mesh map while this frame from my film was warped using the VLCWarper with its included mesh map. The bottom edge is much more clear. I was curious about the differences between the tilted dome and the upright dome. I think that my film fits both but I prefer it in the upright dome because the circle created by the flying objects is parallel with the bottom edge of the dome.

After making sure that I am doing it right, I started animating and after finishing my work

I went to the planetarium to see the whole film. I recorded it and made pictures of each era when being presented. All the pictures and the video are included in the enclosed DVD. I was very happy with the final result and watching my movie in a real planetarium was a very exciting and moving experience for me. It looked just like I imagined it. The following Figure 86 shows 3 individual eras displayed on the fisheye image and in the planetarium, so that the relationship between these two formats is well seen.

Once again I would like to thank Ms. Megan Norris for letting me work in their planetarium, it was a great experience.
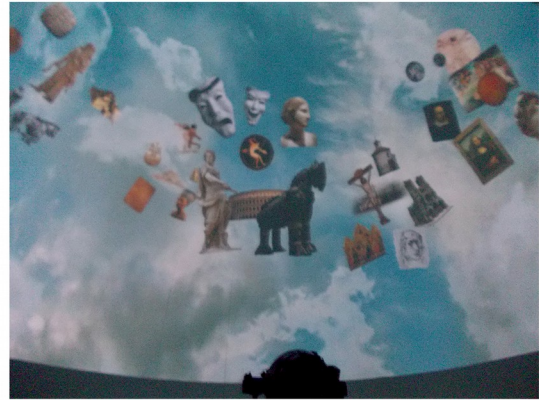
Figure 86: *Presenting the Ancient Rome, Renaissance and Today's world*

Conclusion

Spherical films as a new media have been on a quick rise. The technologies for immersive environment have been evolving equally fast and I am not afraid to say that there is definitely a place for them in the future of the entertainment industry. They bring a new level of 3D effects and reality on the screen and people are getting used to the fact that planetaria are not limited to only projecting stars and constellations anymore. Spherical films may not be as long as classical cinema feature films yet but I believe that within a few years we could go see a new Avengers movie to a planetarium. As a film ardent enthusiast I personally love this idea and I am very grateful that my supervisor gave me the opportunity to work on this thesis where I discover not only technical but also artistic ways to create a spherical projection and walk the readers through the whole process of it. I could juxtapose techniques for creating a classical 2D animated film and a spherical film. I met with difficulties and struggles that would never occur to me if I did not try to make such film myself. The perception of space is completely different, more challenging and more realistic that in any movie projected on a 2D screen. When people go to the cinema they want to feel as present in the action as possible. That is why there are 4D cinemas, bringing other senses such as smell or movement to the audience. If these two ideas of 4D theaters and spherical films combined, the audience would get to experience another level of realistic projection. The film industry will always focus on enhancing and intensifying the enjoyment for their spectators. That is why I think the spherical films are the future. They are closer to making the audience feel absorbed in the movie than any other media before. Learning about them, creating and seeing my own spherical film in a real planetarium was a very enriching experience.

Future work

As much as love animated films, I would also like to discover the process of creating a live action spherical film using a stereoscopic camera. As an animator of my spherical projection I got to control everything that was happening on the dome screen. But making a life action film with actors would include other people in the process as well and I think that especially for the actors the experience of making a spherical movie would be very new. They would have to learn to work and cooperate in a different space and I think that even for them making such movie would be more realistic than shooting a regular movie when they can get off the camera frame and just relax while when making a spherical film they would never really leave the frame because there is none.

I honestly hope and I am looking forward to the day when people will go to see a Hollywood action movie to a planetarium or a dome theater. Just from the recent movies, imagine watching Gravity or Interstellar as a spherical film in an immersive environment.

List of Figures

If not stated otherwise, the images are my own work or screenshots of my work.

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Contents of enclosed DVD

The root directory of the enclosed DVD has the following structure.

- **Images** .... directory containing used images
- **Previews** .... directory containing photos and a video from projecting my film
- **Time_MayaProject** .... directory with the source project of my film
  - renderData .... directory containing rendering data
  - scenes .... directory containing all my scenes and objects
  - sourceImages .... directory containing source pictures for textures
- **film_credits.txt** .... file containing credits and sources of my textures
- **readme.txt** .... file with DVD contents description
- **soundtrack.wav** .... music track of my film
- **time.mp4** .... my final film in fisheye format