Methods for Freezing Time with Computer Graphics Imagery

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Methods for Freezing Time with Computer Graphics Imagery

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Abstract
The most effective method to create an illusion of frozen time in film media was explored for this research. Starting with a description and evaluation of different methods of achieving the effect, this document describes the implementation of a specific technique for a particular project to test freezing time. It was also established to aid students in their understanding of the process in both pre- and post-production. After testing and researching, the method of filming still-posing actors with a high speed camera was chosen. However, the testing and pre-production phase demanded a large amount of time, therefore for the remainder of the project only one scene was established. For budget and time consuming purposes the two recommended techniques are; camera projection and filming still-posing actors with a high speed camera. The choice between these two methods mainly depends on the amount of camera movement.

Keywords: Time freeze, film production, pre-production, post-production, CGI, 3D, camera projection, motion tracking, time freezing,
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1 Introduction

The thought of freezing time has always been intriguing to man. Not just freezing time but freezing the moment as well. This is not possible today with technology and is only seen as something that can be created in movies and films. It is also visually appealing to a great deal of people. Therefore, we want to examine how to accomplish this process for a motion picture. There is a multitude of options for those that do decide that this is what they want in their films. This research paper will examine one method for accomplishing this process.

As in most production, working through a project from pre-production to post-production is a challenging task that can be tackled with a variety of techniques. The research will include most of the elements that are used for planning, however since this project is on a smaller scale, it will not make use of all of them. The research focus will be on the ones necessary to this pre-production. This is also the same for the post-production where it will include more information; however this will not be included in the research itself due to the nature of the project.

1.1 Purpose

By evaluating different methods of creating the illusion of frozen time and how it has been used earlier, we hope to develop knowledge to help apply the appropriate technique for our project. With this knowledge, the aim is to create a film that utilizes this technique to tell the story in our film.

This research project will also provide aid for future students and professionals as an introduction to this effect, as well as it will clarify which method would be the best for their particular project.

1.2 Questions

As mentioned above, there are several intentions that drive us during our research, however in general we hope to answer these questions.

- How does one achieve the illusion of frozen time in motion pictures, with a focus on pre-production and post-production?
- What techniques have previously been used to achieve this effect?
- What are the advantages and disadvantages of these techniques?

1.3 Method

Preliminary, we will evaluate techniques to freeze time by researching the subject and evaluating each method that is appropriate for our project. Meanwhile, theoretical research will be searched on production workflow to prepare ourselves for the remainder of the project. This researched workflow will be a base for the work while altering it throughout the project to fit our production. The chosen method will then be tested while developing our story with events that will help sell the effect of frozen time. These tests will work as an approximate base that will prepare us for the post-production processes and provide us with information on the technical issues while filming.
We planned to have a production day to evaluate timing, technical issues and framing of each location. With a date set for filming, we will complete our last preparations and hire a photographer with a proper camera and equipment. One shot from production will then be chosen to work as an evaluation tool for the remainder of the research while we create our illusion of freezing time.

1.4 Limitations

This research will only involve a small production and therefore might miss some steps that are taken in larger productions but might be redundant in smaller. There is also the limitation of scope this research is investigating. Only the pre-production phase and the post-production phase will be investigated. While the production phase is mentioned in some degree, it is not what the major emphasizes will include, however only to preview that they are a part of the whole that has to be taken in to account and are intertwined with pre and post-production. This research will only focus on the pre-production and post-production on one shot from the movie that was produced, simply because the effects is used in the same method in most of the scenes of the movie.

2 Related Work

Freezing time on the big screen reaches far back in the history of cinema, however it has never been as popular as it is now. Today, we have commercials, TV shows, music videos and several feature films that use it to tell their story. Similarly to macro or micro photography, it is something that fascinates us and draws our attention, simply because it provides a new dimension of time and illustrates it in a method that our eyes are not physically capable of seeing.

2.1 History

The first moment ever of freezing time could arguably be seen as the first photograph ever taken by a camera, the camera obscura. [6] However in this research report, we are focusing on motion pictures and especially the possibility of moving around in a frozen moment. Which pushes us forward in history, before we jump to the beginning of modern cinema, we need to look at Eadweard Muybridge and take a look at his motion studies.

Muybridge studies of motion began in 1872 when the race-horse owner Leland Stanford asked him to scientifically prove the fact that all hooves off a galloping horse are all in the air simultaneously at one point. Sadly, the negatives used at this moment in history were not well developed and often required several seconds of exposure to produce a good result. However in 1873, Muybridge had developed new negatives and managed to produce a silhouette of a horse with all hooves in the air. The experiments were interrupted due to personal life and other events. However in 1877, he obtained much better results. [11] This time he used a new shutter developed by himself that could take photos with a speed of at least 2/1000th of a second. Stanford then sponsored a new project that developed a 50 foot long shed that was painted white and with indicating lines as a reference in the photos. A horse then runs through the shed rigged with 12 to 24 cameras triggered by threads that were stretched along the track. This produced a cycle of photos that were taken with a very low shutter speed with a total time of about half a second. In 1878, he produced the picture below (Figure 1).
and was published in several scientific and photographic journals. The remainders of his life was dedicated to studies of animal and human locomotion and producing several books on the subject that still are used by fine artists and animators as reference in their work. [10]

While continuing his studies, he also took several photos of people in motion from different angles, simultaneously. He achieved this by putting several cameras in a room and aiming them at the same object. Then, he mounted a rig of wires that connected all the cameras to one button and allowed them to shot at the same time. [12] The only detail left was to ask his participants to perform a desired action in front of the camera. The outcome was a series of pictures portraying an occurrence from several different angles; a frozen moment from different angles. (Figure 2) According to our research, this appears to be the first occurrence of a time freeze ever captured by a camera, since it actually is possible to play the images as a sequence and seemingly be rotating around a moving human that is frozen in time.

Figure 1. Maybridge motion study.

Figure 2. Pictures of a moment frozen in time.

Following this, it took quite some time for this effect to reach the big screen mostly because the actual fact that the motion picture camera had not yet been invented. However in 1925, a short movie called Paris qui dort directed by Rene Clair as released in France. [7] It was a breakthrough in cinematography and demanded advanced rigging to create pans and dolly movements of the Eiffel Tower. However, it is the first feature film found through our research, which freezes time. Interestingly enough, the basic technique used in this film is the same used by some of today’s professional studios. Clair simply positioned actors exactly as he wanted them and told them to stand as still as possible while he recorded the scene. This provided the desired effect of them being frozen in time. Many scenes also include both moving
people and frozen people, which works even better since the human eye is attracted to motion and therefore interprets the people who stand still as totally frozen. [19]

Then, there was no major contribution, according to our research, to the effect or the technique of how it was created until The Twilight Zone aired the episode Elegy in 1960. This science fiction series also featured the effect a few times in later episodes and continued to appear a few times every decade. These episodes again used the effect of actors standing still and mixed them with others who were moving and obtained a desired effect. However by this time, the cameras used by production teams had improved and the effect had a better result. [20] [21]

In 1995, The Rolling Stones released their video “Like a Rolling Stone” in which they feature several frozen moments created with two techniques. The main technique that is used, called morphing, uses computer calculations to “morph” from one image to the other. Basically, the computer takes two or more pictures and interpolates an image between them using data from both images. The image below (Figure 3) features a morph between George W. Bush and Arnold Schwarzenegger and show how effective this technique can be. [24]

![Figure 3. Morphing from George W. Bush to Arnold Schwarzenegger.](image)

However, this technique introduces a great deal of smearing of the image and makes it very blurry in many cases, especially when it is introduced as a part of camera motion. Therefore, it is not as interesting as the other technique used called camera projection. The director Michel Gondry worked with the company BUF Compagnie who were developing this new technique. It is entirely based on photographs and simply projects of these images similar to any ordinary projector one might have at home. These projections are cast on 3D geometry that represents exactly what is featured in the photo which provides a 3D camera the possibility to move around in the image as if it is a frozen moment. It is a very effective method of freezing time that brings us back to the first sentence in this section of the report. A photograph is actually a totally frozen moment of time and with the proper technique one can move around in that moment. [23] [24]

Alongside of this time freeze effect, the bullet time effect inspired by Muybridge, led to another method to freeze time that was developed earlier, which caused a major breakthrough with The Matrix in 1999. [44] It featured a famous shot of the main character dodging bullets that amazed millions of viewers all over the world. More amazing though is that Muybridge did the exact same thing, without the use of technology, more than one hundred years earlier. For this specific shot one travels around the main character in super slow motion. (Figure 4)
Technically, the effect is, as stated, based on Muybridge’s experiments of motion and uses multiple cameras to capture the frozen moment. This technique was however further developed starting back in the 80’s by Tim Macmillan who was an artist inspired by the cubist method of expressing objects from multiple views in one image. He became interested in creating a similar effect and exploring time with photographic techniques. His first experiments were of a swimming pool with bathers and buckets with falling water, he called it Time-slice. In 1993, his experiments became publicly known when they were aired on the BBC prime time science program. Shortly after, he was contacted by several agencies and commercial production teams who wanted to use the effect. [44]

The Matrix also made clever use of editing and the major leaps in compositing which had been made to create several other scenes with frozen time. A specific scene in the movie uses this technique together with filming actors who are standing still to create a very believable moment of frozen time in a massive crowd. A big fountain of water is filmed with a large crowd of people walking around it. Shortly after, the main actors are filmed at the exact same location with the exact same camera angle. Then in post-production, the actors are composited over a specific still frame of the crowd to create frozen time. [25] [26]

Recently, the most interesting piece created with a time freeze effect is the commercial Carousel for Philips. It was produced by Stink Digital in London and filmed on location in Prague with a massive crew of one hundred people. Adam Berg was chosen as the director mainly because of a very similar commercial that he had directed recently for JC Jeans in Sweden. [22] He took many parts of his old team and worked with them again to provide the production the experience that was needed. The commercial features a two minute, seam-less camera move that moves through a bank robbery full of explosions and firing guns. It is based on the technique of filming actors standing still but utilized several technical resources that aid the final effect in a majority of techniques.

About six months after the release of Carousel, the creative studio Onesize released a video, “Playgrounds Opening Titles,” with several frozen moments created with the camera projection effect. [8] It is created in the same method as the frozen
effect in the “Like a Rolling Stone” video, however with high quality images and much longer pans on the people. This in turn demands higher polygon counts on the 3D geometry used for the projections. What is most outstanding with this video and technique is they used only one camera, two flash lights and a laptop. Three hours of shooting and the production was wrapped. A timeframe that in most cinematic productions is unheard of. [33]

2.2 Motion perception

One of the reasons why some of these techniques work perfectly is the human eye’s physical method of seeing motion. However, this process is highly complex and is to this date not completely understood by any science. There are many theories that could contribute to explaining the success of filming actors who are standing still. These include motion perception, visual perception, persistence of vision and several others. Unconscious inference is a branch of visual perception and motion perception that aids in explaining the illusion of this specific effect. It refers to how the movement of the body or head is interpreted. We unconsciously expect the objects to be stationary in the images perceived in our brain even though they move on our retina. The brain correctly excludes such motion patterns and interprets them as stationary objects. [27]

Another theory in visual perception is called parallax. Parallax is the difference or change in the apparent position or direction of an object as seen from two different points. [28] In other words while moving, points with differing distance from the viewer will change position on the retina with different speed according to the distance from the viewer. A point that is close to the viewer will move much faster than a point further away. For instance while taking a picture to the side out of a moving car, the trees in the foreground will have severe motion blur while trees in the distance will be clear and seem to be standing still. (Figure 5)

![Figure 5. Example of Motion Perception.](image)

It is through this fact, together with perspective theory that the human brain can perceive depth. In the effect discussed, the parallax motion in the images is multiple times greater than the motion by the characters. This together with theories of motion
perception, such as first and second-period motion perception, explains that the eye excludes the minimal motion of the character in relation of the camera movement or in some cases physically actually cannot see it. [27] [35]

Another phenomenon of visual perception is Persistence of vision that actually was falsified as a theory in 1912 but is sufficient for the explanation of human vision in this research report. [36] This theory explains how rapid playback of video frames portraying an event of motion is interpreted as a seamless motion. A motion picture camera is actually only recording multiple pictures of the event captured by its lens. If it is moving, all these images will be taken from different points in space or when static, they will portray minimal changes in the motion that it is capturing. Again, when all the images are played back, the brain uses memory and complex interpretation methods to visualize it as motion. [26]

This is a very brief explanation of our visual perception of motion and only brings up two of its many theories. However, it is not the focus in this research report and therefore is sufficient in explaining the success of the effect.

2.3 Techniques and their properties

2.3.1 Filming and standing still

Filming actors who are standing still to achieve a “frozen time” effect may sound like a ridiculous idea that is destined to fail, however this is one of the reasons why it works so well. The effect is so intensive to the viewer and therefore at first viewing is, for most people, excluded from possible methods of achieving it. The chapter above explains the reasons why, therefore we want to continue to explain the technical background and techniques of this specific effect. The commercial Carousel mentioned above will be examined and tested. As stated above, Adam Berg had already directed a similar production before and contributed knowledge that sped up the production process. Therefore, it is likely that the development during pre-production was minimal for no references or inspirations from the production team has stated. From now on, the focus will be on the production and post-production of the specific project.

Shooting the film took two days and was completed in seven shots that broke down the camera move into sections. It was recorded at 50 frames per second (fps) to minimize the movement and utilized three cranes and a motion control rig to help repeat the movement of the camera. [29] Therefore, the camera could move at double speed of the actual destined playback speed. When playing back the film, one second of camera movement would translate into two seconds when the film is played at 25 frames per second. In other words, the motion of the character, which already is absolute minimal since the person is trying to stand as still as possible, becomes slowed down even more. If the person moves one millimeter during filming of one second, the footage that is produced can minimize that to half a millimeter of movement per second. In other words, any movement that might be apparent at full playback speed can be slowed down and perhaps placed under the limit of visual perception. On top of that, the production had exclusively hired stuntmen and dancers with an optimum body control to minimize the movement of characters. [30] [31] [32]

When the shooting was over one might think that the optimum quality of the footage would make it easy on the post-production. However, this production demanded creation of muzzle flashes and explosions that are frozen in time which is a very complicated process that demanded extensive work from the post-production
team. Fortunately since a motion control rig was used, they could replicate the camera movement of each shoot exactly to create a “clean” version of every shoot without actors and props. The motion control rig is programmed to move in a certain method where one shot is simply completed with actors, equipment and tracking points and one without. This clean or empty version of the film is an optimal solution that saves days of compositing while removing wires and other special effect props that are there to help the actors. Because when a compositor needs to remove something, such as simply a tracking point, the layer beneath is the empty or clean version where the point that is erased is filled in by the layer beneath. [30] [31]

The advantage of this technique is the decrease of work needed in post-production. If the production team has a pipeline with efficient tracking workflow, only the visual effects needed to be created for the remainder of the post-production. Rather than geometry that helps the illusion of frozen characters, the character themselves are already “frozen” and contribute majorly to the effect. Creating frozen special effects is a task that might seem simple, however it usually involves higher accuracy in all modeling or simulation since the effect is not helped by any motion blur. Therefore, a muzzle flash for instance is in a frame for several seconds instead of a pair of frames. Then, the viewer obtains a very thorough view of it and can see if there are any flaws that otherwise could have been hidden with motion blur. On top of that, the effect demands advanced equipment and special knowledge during the production process that only can be acquired through experience or major research and development. [3]

2.3.2 Camera Projection

In several ways, camera projection is the opposite of filming actors that are standing still because the production processes is many times simpler and instead demands more work during post-production. Camera projection is already explained briefly above. It is created by projecting a still photograph on to 3D geometry that is built to match the specific photograph. This projection provides the geometry correct lighting and texture that in turn makes it possible to move around in the image.

For this technique, the workflow of the “Playground Opening Titles” video by Onesize will be studied. [8] Again there is little information on the pre-production and development of the film, therefore the following will focus on the later parts of the production. Generating the idea for the production, the team wanted a very slow version of a fight scene similar to dancing to classical music. However, filming with a super high speed camera would not work for the team since they wanted more control of the motion in post production. As stated above, the photographer ended up with only two flash lights (flashing studio lights, not flashlights), a camera and a laptop. After production, there is also extensive work needed for this technique to be successful.

To project images on geometry in 3D software the 3D mesh needs to be quite exact to match the image. However, the texture of the image and the lighting information provides information that in turn does not need to be modeled. Therefore, the only concern for the modeler is to create a mesh that provides geometry that helps the parallax illusion. In other word, the modeler needs to be very skilled in creating matching geometry but does not need to create a very detailed mesh as long at the issue of parallax is addressed.
While modeling, the original image also needs to be altered in several methods. Obviously similar to every other image, it needs color correction and compositing. Although specifically for this effect, the background of the image needs to be excluded amongst other alterations. To explain this process, the images below are presented as a guide. Figure 6 represents the raw footage that was produced during the production. To be able to move around in the image the full background that is covered by the character needs to be recovered or painted in some fashion. The easiest method is to take a “clean” photo of only the background much like the second camera move in the Carousel production. However in this case, it has been painted in by a skilled retouch artist. (Figure 7) The background layer will be projected on to a plane while the character is projected by another camera (in the exact same position) to cover the 3D model of the character. [33] [34]

**Figure 6. Original Footage.**

**Figure 7. Background painted in.**
Figure 8. 3D geometry of the character.

Figure 9. The finished footage.
The 3D model in Figure 8 is viewed from another angle to reveal that it exists in the 3D application. By looking closely at the model and comparing with the original image, it is evident that it is not an exact representation of the image, however folds and other geometry that is important for the parallax has been modeled. In the two last images, (Figure 9 & Figure 10) the beginning and end of the camera movement can be seen. With two images, it appears very primitive compared to viewing a video. This representation does not do justice to the effect. However looking closely at the surrounding background of the shoulders where the parallax is maximum, the change can be seen. Combine this cue with several more parallax positions in the image and other visual illusions that contribute to the effect and one can imagine how persuasive it is. [33] [34]

As mentioned above, this technique is very effective for production however post-production introduces a vast amount of effort. There are no worries about human error introduced. Once a photo is taken with a high shutter speed, there is no motion in the objects that are desired to be static. Therefore, it is technically easier on the production since everything in the picture is totally frozen. Issues such as weather and light cannot change in a static image as it can over time in a video clip. Imagine the problems if the Carousel production was set outside on a rainy day or during the fall when leaves are tumbling around in the wind. These occurrences are impossible to change and the entire production would have to be delayed which causes major budget issues and pressure on the post-production team. While using projections, this occurrence would instead help the effect majorly.

2.3.3 Time-slice

Bullet time or time-slice is the third effect that can achieve optimal results with very complex camera movements. It could be compared as an expensive method of doing camera projection. Similar to Muybridge’s technique in the eighteen hundreds, this technique is simply based on firing multiple cameras simultaneously or within a fractional time difference. For this type of technique, a shot from The Matrix is a good example to study.
The images in Figure 11 demonstrate how the shot appeared when it was shot in the green screen studio, as well the final outcome. It is important to note that this technique does not require a green screen studio. However for both production and post-production reasons, it is the method that it was created for this specific shot. Instead of a motion picture camera moving around the object, a massive amount of still cameras are positioned in the path of the viewer. Imagine, the shot above created by a motion picture camera. First, a rig or rail would have to be constructed that would rotate the camera around the character as fast as a projectile, which is probably next to impossible. The movement would be totally restricted to the rig. The motion picture camera used would also have to utilize a tremendously fast shutter speed for the motion not to introduce massive motion blur on every frame. This in turn would require massive lighting for the camera to be able to capture the color of the image.

However, it is easier to use several cameras that have a static position and produce a virtual illusion that the viewpoint is roaming around the character. These cameras can then, as stated above, be controlled to shoot simultaneously and create a frozen moment or within a fraction of time to produce a rotation around an object moving in super slow motion. Later in post-production, the cameras are “painted out” with a green screen removal to be able to put the shot anywhere the production needs. [26]

Time-slice is very effective and depending on the usage can save weeks of post-production. For example, the shot above may also be created with multiple camera projections. This would introduce massive amount of work in post-production since one would have to alter each image and create an exact 3D model of the subject. If the production instead hires a company such as Time-slice Films, which utilizes advanced
rigs that can be altered and specified to a desired motion path, the same result can be achieved. [47] The only post production needed would be to paint out the cameras on the opposite side of each cameras position. However, this kind of solution is especially expensive and not possible for projects with smaller budgets. The motion of the camera is also restricted to pans and rotations around objects. It is of course impossible to create a camera move proceeding forward since all the cameras would be in front of each other. Smaller movements similar to a few specific ones in the “Playgrounds Opening Titles” are also impossible since the size of every camera make them incapable to be close enough to each other.

2.3.4 Compositing freeze frames

Lastly a very efficient method of freezing time needs to be mentioned that is based on compositing. Compositing is the operation of combining two images with each other (see section 3.4). Most well know is the integration of green screen footage onto a background plate. In this case, compositing software is used to remove the green part of the image which in turn leaves the character that was filmed. Surrounding the character is transparent pixels without any color information. Therefore when this footage is laid over the background plate, it seems as if that plate is the actual background of the image and as if both footages were recorded simultaneously. [37] To use this technique for freezing time the compositor simply has to integrate a still frame of objects in motion. Above the still frame, a compositor then can overlay the character and have him interact with the frozen objects. To increase the reality of the effect and make it possible to use with camera movements, the 3D space of compositing software is used. In this method, the technique is quite similar to camera projection. Therefore, this technique could project an image of flying leaves further off in the distance than other elements of a composite. Then, small movements of a 3D camera could be used in the compositing software to introduce parallax in the final clip.

This technique however is not possible to use for instance when the camera movement is large in comparison to the size of the scene. Most of the shots in the “Playgrounds Opening Titles” video use camera projection for shots that are very close to the camera. These shots would not be possible with simple compositing of freeze frames. This technique is very efficient to use in larger scale scenes where the composited element is positioned far from the camera. In this use, it is nearly limitless since the compositor can take any still image on a green or blue screen and easily integrate it into the movie.

3 Theoretical Framework

3.1 Development

Before the actual pre-production, a movie has to be a complete package that has enough funding to make it possible. This process can take several months and can include concept work in all three production areas. A producer has to clear the rights for the story, book or song that inspired the idea to be allowed to write a script. After this, he must convince a production company to provide a funding for the project and to convince them. It usually takes the names of know actors and directors who are willing to work on the project to guarantee a success. In addition to this, a preliminary visualization of the look of the movie is often preferred. All this organization, meeting and research will take time and most of all money. Therefore for those who believe that the film business is all glamour and creative work; film is a product and
entertainment is a business. This might seem like a harsh statement however, it is actually the truth about the entertainment business. [5]

3.2 Pre-production

To begin with, it is necessary to have a thorough plan with every precaution and detail attended to before the day of shooting. This plan includes several different forms and documents that are needed to satisfy the director while providing enough information and setting the right conditions for the post-production team. Planning always occurs throughout the project and is continued even during the post-production process. However, it is during pre-production that a general production timeline is set and most of the planning is prepared. We will include most of the elements that are used for planning, however since this project is on a smaller scale, it will not make use of all of them. The research focus will be on the ones necessary to this pre-production.

3.2.1 Turning a script into a film

The pre-production process starts with the breakdown of the script (screenplay). [2] There are two kinds of breakdowns that split the production into a managerial side and a creative side. A big production would create a break down sheet and a production board to generate the base for a schedule and later a budget for the entire production. These tools are vital for a production manager. However, they will not be needed in this project. Therefore, further reading on this topic can be found in the book, Film Scheduling by Ralph Singelton. [2] Our production includes a shooting schedule which can be read below.

On the creative side of production, a director sits down with an artist to create a Storyboard. [5] The storyboard is most easily explained similar to a large picture series of the entire film. It is an illustrated version of the film that uses pictures and descriptions to show every main detail of a shot. This together with successfully visualizing camera moves in a static element, such as drawings, is the most crucial part of a storyboard. It leads to major demands on the storyboard artist, not only the illustrative techniques but also in editing, composition and cinematography.

Directors usually tell the storyboard artist what they want for each shot and the storyboard artist draws a sketch to see if he has understood exactly what the director wants for the particular shot. It is a time consuming process that demands a very high understanding between the director and the storyboard artist which is why many directors continue to work with the same artist. The storyboard will be altered and changed during production. However, it will remain as a guideline for the entire production team which is why it is such a valuable item.

Hand in hand with the classical storyboard comes a technical storyboard that illustrates more of the technical aspect on a specific shoot. This is an illustration from a top view of the set that indicates the movement of the camera and actors. For the most part, actors only stand or walk on set so they are usually indicated by their position in the beginning and end of the shot. However, camera movements are usually a bit more complicated and are covered in a different approach. Most scenes demand several different camera angles which is why it is very important that they are all indicated on the storyboard. This also provides a great deal of control for the director to play around with the angles and how to use them on location even before he sets foot on the set. Cameras are indicated differently depending on the rigging system used during that shoot. In Figure 12, there is only one shoot drawn, however this simple drawing explains that there are two actors on a set with a camera pan that
Zooms close up on them. Shooting starts on one of the characters and travels with him as he walks towards a table where the other character is waiting. Furthermore, it is easy to add more information to this shoot if it would be needed. For instance, one could add additional cameras to cover dialogue or indicators of special effects. This shows that the technical storyboard is a great tool with a variety of functions. [5]

![Diagram of a technical storyboard]

Figure 12. An example of a technical storyboard.

### 3.2.2 Scheduling

On the other side of the team, the scheduling is being realized in a variety of methods depending on the size of the production. The next process in line for small projects, similar to this one, is the Shooting Schedule. [2] This document acts as a managerial guide during the shooting of every scene. Therefore, every scene obtains its own section of the document that covers everything that is needed on the day of filming. In Figure 13, from the feature film Orlando covers what time of day it is, the cast, extras, props, makeup, set dressing, equipment and several other things. Something to note here, it is a relatively standard scene that, although it includes several extras, could be a great deal more complicated with a seemingly endless amount of information. Still this would not be considered a “bible” on set since many other schedules, like the ones mentioned above, cover other important things.
Meetings and communication

One of the most important parts of pre-production is the communication. This is of course the major factor to keep any project together during all the stages of it, however pre-production creates even bigger demands on communication. Strangely, no film management or film production book was found that included a thorough topic on communication. Therefore, it will be briefly noted to the importance of it during movie production.

During the entire process, it is very important that all departments communicate so things do not go wrong because of incorrect information. To easily handle and organize this massive amount of information, a production is always divided into a hierarchy with teams and their supervisors. Below is a table (Figure 14) of a few positions in a team that shows the lines of communication. All the capitalized personnel are supervisors or team leaders for some part of the production and it is through these key people that information is forwarded through to specific individuals. These supervisors usually have daily meetings and status reports with each other and with the director. In these meetings, it is very important that problems and time limits are discussed so that nothing is missed or creates a problem for the other departments.

Figure 13. Shooting transcript.

3.2.3 Meetings and communication

Figure 14. Table of chain of command.
During pre-production, it is mostly the director, art director, production manager and producer that work on the film. They work in very small teams and develop storyboards, schedules, production design and several other aspects. This work is highly creative and demands a great deal of experience since it is at this stage that they have to develop an entire production. This means that the creative department has to develop looks, character personality, setting, mood, eventual history and every little detail that pushes the story of the film.

Also, the administrative department has to develop an entire budget and timeline for the production from estimates. Therefore, meetings and communication takes place daily at this stage to make sure everyone is on the same track. In every meeting, everyone has a chance to say their point of view and explained different items where ideas have to be changed and formulated for the production to stay on the estimated budget. Eventually, these ideas and designs are elaborate enough to finalize a storyboard and schedule for the next stage of production, filming. [5]

### 3.2.4 Recruiting Actors

As for all productions, the actor is a vital part, and is one of the main troubles and joys. The need for a specialized kind of actor can vary. However due to the main aspect of this project, the demands are a bit unusual. For a still position acting, the actor needs great body control and coordination. Therefore, one might seek out dancers, stuntmen or other athletes for this type of production.

### 3.3 Production

#### 3.3.1 Studio

During the production, the filming may be shot in a studio where most all of the equipment is located as in the décor, the lights, the set, etcetera. These studios are mostly facilitated in larger cities. However, the renting of a studio is expensive; therefore budget has to have it into account during the pre-production, when the budget is determined.

#### 3.3.2 Lighting

Lighting is the art of making a scene, in a studio or at location, believable to the viewer. This is created by the Director of Photography (DP) and on the set he needs the actors for that scene in order to light them, however instead stand-ins are usually used at the same height as the actors. After discussing a preliminary time set for shooting with the Art Director, the DP starts with a light setup that is general and makes sure that the whole scene is lit. Next, one or several lights are set up to illuminate the characters and create a desired mood. When this is finished, the DP notifies the director that he is satisfied with the lighting. (Figure 15) They discuss the results and adjust it accordingly to the director’s wishes. [2]
3.3.3 Special Effects

During production stage the Special Effects Supervisor makes sure everything is accomplished for the post-production to have an as smooth transition as possible. One main detail for the supervisor is making sure that the tracking markers are always visible in the camera and there are at least seven to twelve markers visible in the camera. Following that, the green screen, if used, is evenly lit where the post-production crew would not have to devote more time than needed to basic keying and rotoscoping. If there are any on-set special effects, the supervisor goes through them to make sure everything is in order, and ready for being used in the shot.

For the post-production team to be efficient in their department, they need some information on what the DP has prepared for the shot in terms of lighting and setup, as well as if some visual effects are being applied to the shot. For this being able to be implemented in the shot, the visual effects team needs to have information on how the scene is lit. This information needs to be added to the computer where it can compute the lights where the scene in the computer is lit in the same method as the scene in the real world. How to obtain this information into the computer, the special effects supervisor uses something called High Dynamic Range Image (HDRI). These images store information in them that have different exposures. These exposures helps the computer being able to understand how the light was used and at what strength. (Figure 16)

The method to capture these images is most often created by using a Digital Single Lens Reflex camera (DSLR) that is set on a tripod stand. Then, the camera takes a picture of the set in angles of a complete 360 degree. Therefore when the images are stitched together, they represent a 360 degree view of the set with everything included. These images are later retouched to take out the part that was not created to be seen by the camera and replace it by what is believed to be on the other side of the camera view. This image does not only tell the computer about the light condition, it also tells the computer what the scene looks like and if anything is needed to be added in the shot by the visual effects team. (Figure 16)
3.3.4 Cameras

Before the production starts to shoot with the camera, the production team needs to think about the technical aspects of the camera. First and foremost, the model of the camera has to be chosen. This is not a small task because there are a vast amount of them on the market and they are developing new types of cameras every day. The decision on which camera to pick is dependent on the budget first and foremost. Then, the next question is what type of camera the production team needs for the production. Depending on what style of film that is being made, the production can also vary the camera need for the different shots.

The production will also need at least one cameraman. The need for a cameraman is due to that the camera has to be controlled with ease and be used smoothly; there are many settings that need to be controlled, the lens aperture, the focal point, the choice of lens. These things can become very expensive, therefore that is the reason the production team needs, at least, one cameraman. [4]

3.4 Post-Production

During this part of the film process, the post-production team steps in. To start production, they divide up their different section. The three parts that they are dividing are the: 3D department, the editing department and the compositing department.

3.4.1 Footage

The start of the post-process is of course the receivable of the footage that is to be used in the specific shoot. First in most cases, the production uses a traditional camera that has a film that is made out of cellulose triacetate plastic base. This film material is later being processed with silver halide to create the film which is later sent to the visual effects team. There is more than just the film that needs to be sent to these different departments that does all the post-production. The other types of footage range from location, HDRI and environment. In this phase, it is very important to examine the material and make plans for the adjustments needed to create the desired result.
When filming an original plate, it is very important that a big feature film has an Effects Supervisor whom keeps track of everything that is essential (or rather cheaper) to fix while filming. One example of this could be Computer Generated explosions in a traditionally shoot plate. To match these explosions in the final image, it is much easier to light the scene with colored lights that represent the light that spills on the walls and ground from the explosion.

3.4.2 Editing

Editing is when the film material has arrived from the department that makes it editable for the editor. The director sits down with the editor or editors depending on the size of the production. This phase of the production is very time consuming and usually takes from a couple of weeks to month or even years if the budget allows it to be so. Usually, the editor sits down before the director comes in and deletes the parts that were just unnecessary film shots that may display anyone or anything that was not supposed to be in the scene that the production was shooting. When the director visits the editing studio, the director and the editor sits down and makes a first version of the film that provides the other departments a hint on what will be in the final production.

If the director decides that he wants some totally different approach on the movie after the first version is created, they have to send out the new one immediately where all of the departments do not work in vain. The editing stage continues throughout the post-production time, therefore the other departments obtain updates regularly. What editing accomplish is to make sure the film is making sense throughout the entire film process and it has a good continuity where nothing is in the wrong timing or out of synchronization.

4 Computer Generated Images

Computer Generated Images (CGI) is becoming more common and appears in most of the larger productions from Hollywood. These images are often essential to many of today’s productions to create characters and environments that would have been impossible to feature on the big screen just 10 years ago. These images require their own production team and budget that add months of work to production time. CGI material often arrives to the compositor in several layers. All of these layers are then composited to match the rest of the footage. CGI starts off within a computer application that the visual effect artist uses to enrich the film. There are different types of CGI but mostly it is created in 3D. The visual effects artist uses these 3D applications to first create a model of what was desired to be in the shot. When that is completed, the model gets textured and shaded and lastly is rendered by a renderer.

4.1 Meshes

When creating the model, there are different techniques to accomplish the desired look. The two techniques for creating the model is by either the use Non-Uniform Rational Basis Splines (NURBS) or by Polygons. NURBS is a mathematical model to generate representing curves and surfaces which is shown in Figure 17. [16]

A Polygon is a mesh created by using at least three points in space which are connected to create a surface between these points shown in Figure 18. [48] A polygon is different than NURBS because it can only make an approximation of a model whereas NURBS can make a precise surface of the model.
4.2 Simulation

Fluid simulations are created when there is no possibility to film the desired effect as in the case of freezing time. The fluids that are used in a scene are very difficult to stage to appear as if frozen in time. Computer graphics (CG) presents itself as a solution to create this effect of freezing time. By using a particle based simulation, the fluid can be sculpted to the shape and form as desired. These simulations take time and there are some advanced mathematical algorithms in to make them perform as real as possible.

4.3 Shading and Lighting

Shading is a description of how the model will look when the model is rendered. During this process, the artist decides how the model will look in the aspects of diffuse color, the amount of reflection, the amount of refraction, how the reflection and refraction is simulating the real world objects shading. [17]

When the model has been completed, lights have to be created, otherwise there will be nothing visible. Fortunately, there is a default light. In a computer, the phenomenon of indirect lighting of the real world is a problem to create. In real life, the light from the sun is the main source of light with light that bounces off of everything. This is not how it works in computer applications. In the 3D computer application, there are different methods to make the model believable for the artist. Different lighting methods can be used to sometimes cheat and not use physical accurate computations that are extremely expensive, such as Global Illumination and/or Final Gather to make the lights bounce around the model and scene to create a realistic effect. [18]
4.4 Rendering

These renderers are an application of highly sophisticated mathematical algorithms that creates an image of the model based on the texture and the shading information that the Visual Effects Artist provided to the application. The rendering of these images are not always completed by just one computer. They are rendered together with a Render Farm. A Render Farm is a collection of computers all connected to a network and uses a special application that is specialized in distributing the computer power of all the computers in the Render Farm to speed-up the rendering process as much as possible.

These renderers create images that are not a complete image that a normal person is use to seeing. The images that the renderer keeps creating are called passes or render channels. These images are stored during the rendering process in a frame buffer. When the rendering is completed, the frame buffers are put together by the renderer and then the final image is presented to the viewer. Then, the frame buffers can also be exported to the hard drive where they can be utilized by the compositor. These images are part of a full complete image that a person can view. Later, these images are composited together by a compositor.

4.5 Set extension

Set extension is simply a technique of using photos or paintings to extend a sequence in film. Usually, it is created by extending or replacing the background that the characters are in to beautify the shoot or simply place them in the correct setting. Today, the most obvious example of this is the motion picture Avatar which features a complete use of CGI for the environments where the characters are acting. However, the most common and historically used method to create set extensions is matte painting.

The art of matte painting reaches back many years further than CGI and compositing in general. It is represented by a photorealistic painting created to be used as a back plate in massive shoots. Therefore instead of using several artists to create a 3D environment, one artist paints a 2D painting that replaces the background.

4.6 Keying

To integrate actors in many of the images as in Figure 13, they are filmed in a studio against a green screen. The underlying reason for this color is that a compositor can set the computer to delete this color from the movie more easily. It is because of the computers range in color spectrum where a computer is built up from the basis of Red, Green and Blue (RGB). They are the core components that every other color is derived from in the computer and it makes these colors the easiest to delete which is shown in Figure 19.
Therefore, the color of the “screen” varies depending on the purpose of the shoot and the clothes the actors are required to wear. There would be an incredible difficult job for the visual effects team to have an actor be in front of a green screen and at the same time have green clothes. For the human eyes, it is rather easy to see what is in the image, however the computer only sees a computer file that contains RGB information. It is impossible for the computer to remove the green screen without removing some of the actors’ clothes.

4.7 Match moving

Match moving is the process where the post-production team is placing the CG in the film that was shot in the real world. As mention before, the computer is not intelligent in the part of perceive depth and other cues that is easily perceived by a human eye. The human uses the different monocular cues and stereoscopic cues (binocular cues) that the human brain perceive and translates into a three dimensional world. [9] The monocular cues are:

- Lighting, how an object receives light and is shaded together with shadows; an essential cue on how the object are in correlation to the room.
- Then, there is always the size of an object relative to other objects. The most prominent for the eye is the perspective, which is when parallel lines of any object are converging further away from the observer.
- Another example is Occlusion; the blocking of objects. This provides the observer a cue to the relative distance between different objects. In Figure 19, the brain evaluates these cues to predict the distance between the different object in the world.

![Figure 19. Before and after the green has been keyed.](image19)

![Figure 20. How a tracking marker can appear.](image20)
For a computer to match the same concept is not that easy. The computer is not intelligent enough in evaluating these different aspects to perceive the three dimensional world of the image. The computer information needs to be provided to easily determine the depth and dimension of the world. Therefore, tracker markers are used which help the computer application to understand and view. The computer application uses trackers to identify marks in the shot to easily add a tracking feature in the application. This feature is together with more features (depending on the application) during the whole sequence that will have added CG.

The best solution for a tracking marker is to have lots of hard edges and high contrast that is what the computer application can see with ease. (Figure 20) These features do not always have to be in the sequence, for there must only be a minimum of seven features in the sequence at any given time. The application inspects the motion of these features and since there is parallax in the picture, there will be some features that move less than others and some that moves faster than others. Later, this is useful for the application to determine the distance between the features and also the camera move. This data is from the tracking that has been solved and transferred to a 3D application in which the camera move is laid out in order for the 3D department to start matching the 3D with the live footage.

4.8 Plate matching

Plate matching is the essential job of the compositor and is required to make a believable final image. This is the process that uses most the tools of a compositor and renders an image where all the different “plates” (or footage) is color corrected and matched to each other. However, the final image is not distinguished from the one shot as is shown in Figure 21.

![Ungraded Image](image1.png)

*Figure 21. The grading makes sure that every shot holds a theme in color.*
4.9 Sound and Music

One major important aspect of a film for most productions is the sound. Not many films come with a silent theme. Therefore if the film comes with a sound theme, it is added in post-production by a composer that obtains the edited film. The composer can then have a sense of the film sequence and the score can be composed. If there has to be any sound effects, they are also being prepared under this department.

5 Choice of Method

For this project, the above research was necessary and could not have been completed without it. Several methods for creating scenes were evaluated and adjusted to fit a specific need to later decide which of them to use. To begin with, this production never had a large budget which in turn led to a quick decision of excluding the bullet time technique. However, the rest of the techniques are much harder to decide between and each has their own advantages.

A list of demands was never created but rather became clear throughout the tests and evaluations. Nevertheless, a variety of the demands that were apparent to create the film in the desired method are listed below:

- Seamless camera movement
- Control over the motion
- Small budget
- Slow camera movement
- Smooth camera movement
- Image quality
- Time
- Equipment

The final choice of method or rather the main method was to film actors who are standing still. There are several reasons for this even though most of the points above rather pull the decision in the other direction. Compositing freeze frames over footage were however never capable of producing the image quality desired for this effect. Therefore, the final decision was between camera projection and filming. One of the first decisions made for the project was to have a seamless camera movement. However, both methods have this opportunity even though it introduces more work with the camera projection technique. The three next points are very strong in the camera projection technique. For instance, the camera movement can change totally in post-production and all of the movements are totally smooth.

Filming actor demands advanced equipment for the production and in turn demand a bigger budget. It was the last three points that after viewing multiple videos with both of the effects and the access to equipment that finally made the decision. Image quality is one of the main points in a motion picture, therefore had an enormous impact on our choice of method.

After a few weeks of work and some contact research, we acquired a RED ONE camera that could record our camera movements with high resolution and high frame rate. This fact provided excellent capabilities in producing high quality imagery with a motion picture camera. The technique utilized by Adam Berg of recording at a higher frame rate and then slowing it down in playback could also be utilized. There was only one problem with this and after a few tests, we realized that obtaining a smooth
camera movement was next to impossible without advanced camera rigging. However, a few days later this problem was addressed by hiring a Steadicam operator which made it possible to have smooth camera movements with greater control over the motion on set.

6 Result

6.1 Development

This project begun with an intention to create a short clip with the desired effect of teaching ourselves the integration of CGI into footage that would have industry quality standards as a goal. One of the major inspirations was the commercial Carousel directed by Adam Berg. It won several prizes and had an enormous success similar to Paris Qui Dort and The Matrix. [30] These films are all factual proofs that the effect is in demand and usually contributes to major success. This together with a personal affection for the effect was a good reason to choose it as the goal for our thesis project. An extensive research was completed on the effect and how it had previously been made, which was noted in chapter two.

6.1.1 Developing an idea

The idea for a movie usually starts with a feeling or a certain meaning of what it is all about and most of the film uses situations and a story to enhance this feeling. The first goal for this project was however to create a visually stunning experience for the viewer. Therefore, ideas generated for the project was special in the manner that they focused on selling an effect. However to make the short movie more interesting, there was a demand to develop a story.

The final idea was set for a huge concept of a frozen moment when the earth is about to end. A plot that might seem cliché, however it presents perfect conditions for activities that are in rapid motion. Deciding early on to have a seamless camera movement that would move through indoor and outdoor scenes was a step that helped restrict decisions and form the project. Some of the ideas we wanted to implement were:

• A man committing suicide by jumping through a window
• People running
• Water splashing
• A man falling
• A woman crying
• A woman throwing porcelain

6.1.2 Story and scenes

The story for the project consists of five scenes that all happen in one frozen moment while the world is going to end. It has changed constantly throughout the entire project and may also change during post-production. It is based upon a psychological model called, "Kübler-Ross" (Five Stages of Grief) and fits our idea by showing how people deal with death. [17] In this model, there are five stages that explain the different methods in which people deal with grief and tragedy. Denial, anger, bargaining, depression and acceptance were feelings that all could be adapted to the story and provide a meaning that would lift the final product. [15]
Starting with denial, the film continues with one person for each feeling. On the technical side the first happening is a man pouring up whiskey, which of course is totally frozen. This presents a technical difficulty that is especially apparent since it is a slow camera move on a glass and bottle that are empty. They have to be filled with frozen water that exactly fits the proportions of the containers and is correctly rendered. Since there is an extreme close up on the objects, the tracking is very important and difficult since static tracking markers are extremely hard to find on reflective and refractive objects. Another difficulty that is present in several scenes is the windows. The story is set in one huge apartment building and the actual production locations are set in completely different buildings. This means that the compositing stage needs to address this issue by changing the exterior of the outdoor scenes to fit the final scene.

In the next scene, anger is the feeling. There is a woman crashing a wine bottle with a baseball bat; an action that demands complex simulation between static objects and a fluid. Therefore, this scene has had an enormous technical development and is the base clip for this thesis.

Next, we have a man who is bargaining with god in his last attempt for mercy and forgiveness. It is a calm scene with interesting details that breaks the motion of the movie and provides an interesting touch.

For the depression effect, a man shoots himself in the head while he is looking out of the window; a very technical scene that demands a great deal of attention. However on the positive side, the exit wound is only visible in a short amount of time further away from the incident. On the other hand, there is a strong light that needs to blend with the CGI footage, which makes a very technical shot because of the difficulty in tracking.

Even though there are quite a few technical scenes that need a great deal of attention, the last scene will need more work and is definitely the most difficult when talking about the post-production. The entire scene will need tracking and many elements to composite. It begins in a street where the camera moves through and pans until stopping on the main character. Parts of the street have to be replaced and since there are not enough actors or cars on production day, it is likely that these elements will have to be added as well. On top of that, buildings will need to be destroyed with realistic meteors that crack structures and concrete.

6.2 Pre-production

6.2.1 Effect research and reference clips

Above is an entire chapter on research and development of the techniques which was use for the project. However, this section covers a few other aspects that were researched and contributed to the rest of our development. When a decision had been made on a technique to base the project on, frozen moments needed to be researched, as well how exactly things appear in slow motion. Other than that there was several more aspect of the project that needed to be developed.

Since a constant camera move that did not cut from clip to clip was desired we needed a solution was needed to get through one apartment to the other. The first suggested solution would be to always move straight through the walls and sort of dim down to black for each wall passed. This would be created together with a few open doors where the camera might pass people running out of them. Testing these
solutions made it clear that it usually introduced problems in the camera movement instead of providing the desired solution. Instead, a suggestion of actually passing through the walls was evaluated. This was a solution that worked much better with the camera moves and also added a visually interesting element.

![Image](image.png)

*Figure 22. A snapshot at how a wine glass breaks.*

Most of our research, except for the actual base technique, was on slow motion videos and how things actually appeared in slow motion and frozen moments. (Figure 22) Especially, YouTube became a good resource and some TV shows that are dedicated to slow motion effects. Many of these videos also contributed to a few ideas and how to portray them in our story. With several scenes including fluid simulations, it was a key element that needed to be researched. First, one realizes that splashing water does not have much foam in it. Comparing a water fall to water cascading from a small bucket might seem ridiculous; however it provides excellent information that is not realized by viewing the water with the naked eye. Pouring water from a bucket does not include any foam at all. It eventually breaks up because of the air resistance that increases while an object falls but no foam is produced. [46] What happens is that the water forms small droplets that are obscured by their kinetic energy. For foam to be developed, the water needs to undergo extreme pressure that creates very small bubbles of air and this simply does not occur while water is being poured into a glass or even hit by a baseball bat.

Cracking or shattering porcelain and several other types of material was also needed for a few different scenes and research showed how differently materials react when they are broken or demolished. Porcelain which was meant to be used in the kitchen will crack in several pieces. However, all of the pieces appear to have very clean edges. The first test that was created was a simple cracking of a normal plate.

A great deal of research was also made on the last scene through watching movies and methods for creating meteors. The study on cracking/shatter was helpful since a building was needed to be demolished and shattered into multiple pieces. When looking further into different materials, it also became clear how wood breaks into splinters and metal rather bends than breaks. Meteors are also very important for the final scene and to create them a specified method needs to be chosen. For instance
while searching for real meteors, strange looking pictures were found that do not seem correct but actually are exactly what they appear similar to reality. (Figure 23)

![Figure 23. A real meteor seen in the sky.](image)

Therefore to create a realistically looking meteor, research was achieved by watching Hollywood movies and how it is portrayed by other professionals. It turns out that they appear nothing similar to real meteors but they provide a much better visual experience for the audience. Below is an early example of a meteor created in Autodesk Maya. It was created with a simple animated particle emitter and a puffball preset. In Figure 24, meteors were created to resemble the ones in the scene from the movie Armageddon which was the aim.

![Figure 24. A test render of a 3D meteor.](image)

### 6.2.2 Filming for visual effects

To implement CGI in film it is, as stated, necessary to track the camera. Researching the art of tracking provided general information on how to do this. However to make sure that it would apply on the project, it was necessary to shoot them as a test. While testing camera angles and composition, a few attempts with placed tracking markers was also created. Later this footage was tested in tracking software to make sure it was tractable. It was clear that our scenes would track fairly easily and provided confidence in that area.
Another important thing that actually was not tested at location was HDR images. They are exceptionally important for creating correct lighting within a CGI scene. However testing the technique with similar HDR images provided an approximate and satisfying appearance for the final result.

6.2.3 Test shootings and pre-visualizations

As was mentioned earlier, test shootings were created throughout pre-production. This work was highly important and provided ideas and decisions that changed the story, techniques and several other things for the entire project.

Some of the first visualizations were images taken of the location for the end scene. They revealed the location and created thoughts on how it could be used for the film. A few tests of creating the location in 3D were also created to test the possibility of this integrated with camera projections. However, the development of these tests did not make it very far and when the availability of an advanced video camera was presented these tests were dropped in favor of the other technique.

The first video test was created after the first draft of our story. It visualized a method for all participants of the project to see and argue upon a single appearance. It also provided experience in all camera attributes that needed to be tested on location. Before this, there was no notion of timing, space, speed and several other aspects that were provided with just one test. The story was then changed after the first few camera tests that clarified that it would not work with the attempted camera movements. Indoor scenes were easier to visualize and therefore also easier while executing them. However, the outdoor scene demanded special attention since the movements were on a larger scale and the location needed to be altered in post-production. Some of the buildings are for instance not as suited as the others for the film. Therefore, these buildings had to be avoided as best possible to minimize the post production.

Early in the project, the story did not have a real point to it and the reason for creating the film was rather focused on the visuals. Even though this was known throughout the project these visualizations helped realized the importance of an emotional meaning. A story was discussed and processed until the idea of using the “Kübler-Ross” model was born and the actual meaning of the film took its final form.

[49] It was natural to place all of the events in the same building because of the difficulties of creating a high-quality camera movement in the exterior scene. It also led to the further development of the wall passages which was mentioned above. When a few tests were filmed on location with the wall passages, a realization appeared, it felt strange to view the whole film in one cut.
Figure 25. A technical storyboard showing the camera movement.

Figure 26. Second technical storyboard.

This image in Figure 25 clearly shows the logical problem of the camera movement. We needed to change the entire camera movement to obtain a natural flow in the placement of the apartments. The image shows the most specific problem occurring going from the bargaining scene into the depression scene. There would have to be a hole in the wall and a major gap between the walls for it to be possible to position each apartment in such a manner. As a result, a suggestion was made to work with the main window (marked “key window”) in the Bargaining scene which solved it by replacing the entire environment outside the window to make it seem as if the building
had an inner courtyard. However, this solution would need massive work in post-production. Therefore, an idea of simply putting the office scene in a different level of the building seemed like a much better choice. It also introduced enrichment in the variation of the camera movement since it breaks the direction in which it is moving. Figure 26 illustrates the new camera movement where it simply drops down from the Bargaining scene into the office.

6.2.4 Camera and photography

When the base technique for the project was chosen and much of the story was established, the team as stated had acquired a RED ONE camera [14] and a Steadicam operator. [13] The advantages of the camera are quite obvious since it produces such a high resolution for an optimum image quality. It also generates 32 bit images with a very high range of color information. This means that the color correction has a huge amount of information available in contrast to normal 8bit RGB images.

Through several of the test shootings, we found that our footage needed to be stabilized or maybe would not be possible to use without advanced rigging systems. By acquiring a Steadicam operator, the camera moves would not only be smooth and stable, it would also be able to move around. Another solution would have been to rig every scene with rails and cranes. However, this would demand a much longer rigging process, very restricted movements and maybe would not even be possible in some cases. The Steadicam provided the freedom desired in the camera movement and it could be changed from take to take while filming. A Steadicam also removes any painting operations that needed to be created which in most cases are apparent when using a rail.

During test shooting for the remainder of the project adaptations were made to the movements which were possible with Steadicam. However, there were very few movements that were restricted on the Steadicam especially for the ones that were desired for this project. The only real problem would have been to create a pan from the top of a building down to the street, which was written in the first draft of the story. However, this movement was excluded quite quickly since it was out of the project budget.

6.2.5 Props and equipment

Several props and stage dressing was discussed for the film, however very little of it was used in the end. The most specific things that needed to be acquired were a pistol for the suicide and a few cars for the end scene. To support characters in specific positions a few rigs were needed to help them balance. Removing them from the final footage requires them to be green, however this paint was hard to acquire since it needs to be completely green.

Other than that equipment was needed to help with the post production. Several tracking markers were printed and were stuck to the walls of every scene. For the floors, ping pong balls were cut in half and put in strategic places. This is because tracking markers are distorted when they are stuck to the ground, therefore the half balls work well for this. To recreate the lighting of the 3D scenes, reflective ball was used where photographs were taken from four different angles. These images are then used to create HDR images that replicate the lighting on the 3D objects.
6.3 Production

6.3.1 Working with actors

To succeed with the frozen effect of people, they have to stand very still. The problem with this is that a huge number of frozen positions are hard to maintain for an average person. Especially since many of the positions have to be ones that usually are characterized with rapid motion. This is solved by a support of some kind. Specific positions like falling need very advanced types of support that usually need to be constructed to support the correct parts of the body. However, this production ended up with positions that are quite easy to maintain. The hardest position to support was running, although this can be solved by a support for the front arm and the back leg. It does not need to be an advanced support rig since it is only needed to balance the person. For this project, the solution was to provide individuals who had a hard time balancing, sticks to support their arms and boxes to support their legs. The position that was developed the most was in the first scene when pouring whiskey into a glass. It was first thought to be very easy since the actor can sit down, however holding out the arms in a completely static pose and for several takes in a row can be very exhausting. Tests to solve the problem were created by small rigs consisting of steal wires and blue-tack that was painted with green color. These were then attached to the glass and bottle for the actor to support his arms on.

Other issues than position and balance are more important when moving closer on characters. A person that is in frame for a long period of time also needs to maintain a static face and most important of all keep from blinking. To solve this issue each actor was cued just before they entered the frame. This also helped them to maintain a very static moment of a specific pose.

One of the scenes was also in need of stage makeup. This was decided upon after a few tests of creating flesh wounds in 3D and seeing tutorial videos of how to do it with makeup. It was apparent that a small hole would be much easier to create with makeup than in 3D.

6.3.2 Filming

For filming, the team arrived at the location where they were supposed to shoot one specific scene. Then, equipment was brought in that was going to be use; this was the camera rig, lights, Steadicam rig and electricity outlets and extension cables. This was mounted and placed in the correct location by the crew. During this setup, the VFX supervisor went around and placed tracking markers on the set to have the best tracking solution as possible for later in the post-production phase. The filming was created as described before with a RED ONE and the camera was set to film in 120 frames per second (FPS), at a resolution at 2048 pixel by 1024 pixel. All the material was also recorded in raw format; a format that does not contain almost any compression. When the filming started, the cameraman and the first assistant camera operator moved in the outlined path. When the take was finished, the ones involved looked at a preview of the take through a small viewer. This take was evaluated and then stored for later editing.

6.3.3 VFX and SFX in production

While shooting for the film, the post-production was in our mind the whole time. There were some difficult things that were not to our advantage. First, one scene had to be shot outside which had elements that no one can unfortunately control. Therefore for that scene, none of our actors could have any clothes that were wide, large and easily caught by the wind. For a time freeze, there cannot be any type of movement in
the picture other than the camera movement. Therefore to make the clothes seem natural some special effects were added such as wires. These wires help to add the illusion of wind that we could control. If a person is running and the time freezes there are movements in the clothes and this movement wind, which had to be recreated to sell the illusion of movement and the time, had to be frozen completely. These wires were hidden underneath the clothes to limit the post-production part as much as possible. There would be a difference if freezing time had to be recreated inside a room.

The next issue was to make the computer understands and filming in the real world. The computer needed to see that there was depth in the picture; therefore some tracking markers were used. These markers are made to appear in a special manner in order for the computer application to view it as best as possible. The placing of these markers was created during the lighting and rigging of the scenes. After the first take, the film was inspected to see if there were enough trackers visible in the shot. If not or if some were only visible under a short period of time, the markers had to be moved and added where they were visible longer in the shot. Because the shooting was in apartments, there was some problems with the space for the cameraman to move, creating some issues with the markers. The cameraman had to move in a manner as not to bump into anything. There were also problems placing these markers because of the confined space which did not allow for the parallax to be visible. As soon as the first take was finished and checked, there was a certain relief that the parallax was sufficient for the application to handle.

6.4 Post-production

6.4.1 Editing

The editing will be completed later when all the scenes are post-processed to easily correct any timing issues that may appear. This will provide the 3D department a large amount to render and to composite together. However, it will lead to more flexibility when we arriving to the phase of editing.

Since every shot will not be ready in time for when this research project is due, we will not go further for we have not been able to evaluate the difference between the described methods and how we will end creating it. Nor have we had any difficulties with this part of the post-production as of yet.

6.4.2 Match moving

To be able to match move the sequence, black and white tracking markers were used. These tracking markers had to be placed in specific places where the camera could see them and where there was also some degree of parallax in between the tracking markers. For the scene that was shot outside, the tracking markers had to be scaled where the camera could always see them clearly. If the shot had no clear tracking markers, there will be a great deal of delays in the post-production. Therefore, there is always a need for a visual effects supervisor at every scene.

The supervisor made sure that after every take the tracking markers were visible enough and there were enough tracking markers in the camera at all occasions. For the scenes shot inside of a room that had a confined space, there was more to think about in terms of obtaining the amount of parallax that is needed for the computer application to solve the scene and understand it. When the tracked shots were finished, they were brought into the computer application which was PFTrack by Pixel Farm. [38] In this application, all of the tracking was accomplished, where a room and space
was obtained with the help of the tracking markers. This phase took us about one week of active time to achieve a satisfactory tracking solution.

### 6.4.3 Three dimension

Once the camera movement was accomplished from PFTrack, the three dimension (3D) application of choice, which was Autodesk Maya, was chosen to model a wine bottle and a carafe that the actor had smashed in the shot with a baseball bat. [39] (Figure 27) These models later had to be simulated to be destroyed and the water and wine had to be splashed away. This part of the 3D phase took time which was because of the heavy fluid simulation. The fluid was simulated in an application called Realflow by Next Limit. [40] Fluid is very cumbersome in terms of speed and efficiency for the amount of calculations needed to be created. All of the fluid simulation is incredibly advanced algorithms. When the simulation stopped, the result for this small project took about three hours which was not much time since it was only simulating a wine bottle and a carafe that was filled with liquid.

![Figure 27. A simulation of the bat, the wine bottle, carafe and the fluids.](image)

Shading was the next step of the procedure where the textures and shading of all the objects were created to represent the same as in the real world. After that stage and everything appears correct, the lighting was the next item to remedy. A HDRI was used to create the overall lighting and provide us the temperature in the lights in order not to have a great deal of guess work. The HDRI images which were created in the production phase were taken into Adobe Photoshop. [41] First, in Photoshop, these images were converted into one 32-bit float image. This image was then brought in HDRShop for unwrapping the image to a longitude/latitude image which flattens it out. [42] Then, it is brought back into Photoshop for further changes. In Photoshop, this image is used to create a 360 degree representation of the room that was shot in the scene. Together with the other HDRI that was taken from different angles with the same mirror ball, and had the same procedure to be created as a flat HDRI, they were overlaid on top of each other in order that their seems would match up and finally create a 360 degree HDRI. Some lights were added to obtain the exact feel in the shot that was wanted. And finally, we could start rendering the scene to images and move on to compositing them with the live footage.

### 6.4.4 Compositing

During the compositing in the post-production, a high-end compositor, Nuke by the Foundry, was used. [43] Nuke was selected due to the capabilities of a node based compositor which has the ability of working in an immense structural project. At this point, the rendering part was mostly completed as the compositing could start on the already finished images that the 3D department had created. At the same time, the
footage from the film was being prepared to add the CG into it, which was removing the tracking markers by first using our tracking data and using a part of the image to paint over it. This was also created on some other things that were not able to be hidden in production, such as extension cables.

7 Discussion

7.1 Pre-production

Many differences appeared in this production to the one which we plotted out by reading books explaining an example of workflow. Generally, this was because it is many times smaller than the large productions portrayed in production books. However, development was a huge part of our production just as it is for any feature film. We focused on very specific research that demanded extra attention and while the study in technique is apparent in any general production. This project was special because the visual effects were the starting point and the story was developed from that desired effect. Generally, effects are just a byproduct of a larger meaning, something that strengthens the experience. Therefore, the story development was quite restricted since there was no character acting and an effect that aimed the entire production. In this sense one does not think “I want to portray this feeling in my new film. Instead this statement is in a way transformed into a question of “What can I portray with this effect?” which we saw as an opportunity rather than a restriction. This is also true for researching for a movie where one might look at classical locations or future designs depending on the story. In most productions, this research is on visual designs for characters and locations that are specific in creating a correct setting for the film. Our production research instead focused on specific visuals and time alterations; research that was absolutely necessary and demanded much longer time than we anticipated.

In the beginning, there was a goal of creating a visually stunning film. Our work consisted of everyone contributing to the ideas and working together. It worked well, however sometimes things became confusing since no one had actual responsibility for anything. We did organize the group a few days before production but this was a few days to late. This decision should have been made earlier to provide us with better control of the situation. Everything turned out well, however small things were forgotten because in the beginning no one person was assigned to the responsibility for each thing. (Figure 28 and 29)

While test shooting for the tracking, it was never anticipated that shooting with such a big amount of depth of field would be possible. However on the actual production day, it was used extensively and has made tracking quite difficult in some places. Luckily, the objects that were supposed to be tracked are often in total focus which makes it easier to track. One specific point with a problem is when the camera leaves an object and changes focus while it still is in frame. This could have been avoided by one test shot on production day to see what parts of the images would need extra tracking points. However, it was not realized at the time since the focus laid on the esthetical side and obtaining all of the footage that was needed.

Poses of the final scene were not as visually convincing as we might have liked them to be. This specific scene was tested several times, however on production day it was still hard to know exactly where we wanted everybody and again the team could have been more organized. We probably also could have made a better solution for maintaining a believable running position with good support.
One of the larger differences from our example of workflow is the planning. Many big productions utilize shooting schedules, storyboards, production strip boards and many other things. Our production simply had a single paper printed on both sides with all the props we needed for the production day. This is something we definitely could have prepared better but ended up without. However, it did not create any major problems and worked fine for this smaller production.

7.2 Post-production

In the production part, it is worth noting that, we had prepared some help for the actors for some scenes where we wanted some more dynamic poses. This prepared help was wooden sticks that were painted in a special green color with the post production in mind to easily taking them out. However, these helpers were not used. For the actors managed to stay still long enough to not use the help sticks.

In the post production phase, we were not expecting as much trouble in the production. The main problem was related to transferring files from one application to another. When moving the simulated data from Realflow to Maya, there was a strange offset which was not viewed in our pre-production research where everything went rather smoothly. This also happened when we transferred the raw camera data from PFTrack to Maya, as the camera did not really match any longer. This was not expected, however these program conflicts are mentioned on the internet that they are notoriously hostile against other applications and production time.

What was realized during the tracking process was that it had some difficulties with obtaining good trackers to stick to the same position under long enough duration to make a respectable solution. This was due to the fact that during the filming, a very short focal length was used. It provided some great looking depth blur effects, however it did not help in the tracking as the corners no longer were crisp and sharp. The application could not analyze the image in an optimal manner, as well as the focal length varied, which is not satisfactory for tracking programs. If the focal length varies, the depth parallax is changing. It makes it extremely hard for the application to know where the tracking marker is in the image. This proved to be a challenge that made the phase for tracking to take longer than expected.

Another problem that was not anticipated was the HDRI, which was due to an overlooked step that was not realized in the production and led to some low quality HDRI. The quality was still high enough to be used in the sequence, however not as accurate as foreseen. The images that make up an HDRI were not coherent. They were not lined up the same for the camera had moved when the exposure was changed. The one with the longest exposure time was also rather blurry for the camera was hand held. This could have been avoided by using a stand for the camera to take all the shots and then moved to the next angle to redo the procedure there and so on for a total of four times to obtain a whole mirror ball representation of the room.

The rendering took some time because rendering fluids that is refractive is difficult to provide a realistic appearance, as well as a large amount of images that had to be rendered. While trying to optimize the render time, as much as possible, there was still a great amount of time that we were never able to eliminate which was associated with the refraction and reflection part of the render. These parts of the rendering was vital for our project, mainly because the nature of transparent objects and how they bend the light when it goes through them. This was not something that could be compromised which left an immense rendering budget that had to be taken into account.
8 Conclusion

It is safe to say that it is possible, even with a quite low budget, to create the effect of frozen time, however it is a time consuming process and demands quite a great deal of research to be completed correctly. We have researched many of the techniques available and found that they are all applicable and do a great job, therefore the choice between them usually depends on the type of budget and timeframe the project is under. Most used in the professional industry today is firstly the method of filming still objects, using camera projection in 3D software to move a the camera in a still picture, Time slice (or bullet time) and compositing still frames.

Choosing between these can be a bit tricky; however we found that while they all do a good job the real choice is between filming still objects and camera projection. Compositing freeze frames are very easy and cost effective but do not really sell the effect unless it is combined with one of the others. Time slice is a whole production team in itself and is very expensive therefore this option is usually only applicable on large projects with big budgets.

Most cost effective is camera projection. It only needs one still camera and a 3D software capable of projecting images. However to build an entire movie on this technique is quite hard and demands a great deal of planning but most importantly a huge amount of work in post-production. On the other hand, it provides great flexibility and allows the director choose and alter the camera path whenever he wants.

Filming still objects is tedious on set and in post-production however it allows for greater seamless camera moves and is very effective if utilized correctly. If possible, it is advised to use a motion control rig to minimize the post production work. However, it is possible to do it with a steadicam rig as this thesis as shown. On the post production side, this technique introduces camera tracking to get the camera into 3D and placing still 3D objects. This technique can be created without any 3D at all if all scene objects are on set. However, this usually introduces wire removal and painting.

The technique utilized in the thesis is the technique of filming still objects which relies heavily on laws of visual perception and how we can trick our minds to see things that are not really true. It basically demands two things; a camera that captures good quality images while shooting at high frame rates and actors or objects standing still. Then, filming at double (or more) speed and then slowing it down creates the illusion of a totally frozen moment. Simply because the small accidental movements made by the actors or objects are too small to see.

It was the best method in this particular case since the camera movements are quite great in every second of the film. Tracking some particular shots has proven to be quite difficult, however to project enough images for these great camera moves would have been a huge process. In other words, it is recommended to evaluate every aspect of the project before choosing between these techniques since they all have advantages and disadvantages. However, the proper recommendation would be to use camera projection for projects with smaller production budgets where the camera does not have to move great distances. Considering that, it introduces big workloads in post-production. For the slightly bigger projects where the effects are apparent in large camera moves, it is advised to film still objects.
Further research

After the chapter about recent works, there is the question if there is more to experiment on this subject. We consider it still to be viable to perform more research in the area of implementing the other techniques together or just focusing on mixing two techniques. This phenomenon will not stop exciting the human mind; therefore there are still areas to research. Especially in combining the techniques and making the process as simple as possible. There is with certainty room for making the process more efficient.
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