Expressive, Digital Storytelling -

Utilizing Non-Anthropomorphic Attributes

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Abstract

Cinema, Film and Visual Effects; the art of illusions. Technology has drastically improved over the years, providing us with more computer power and effective methods of portraying realistic visual effects. Photorealism and Hyperrealism are two art styles that are becoming progressively more applicable within everyday films and television shows. Visual effects are becoming difficult to distinguish for the common audience, when comparing live action footage to computer generated imagery.

This research revolves around the investigation of realism and expressive storytelling. The expressive storytelling investigation will explore non-anthropomorphic attributes through character and scenic elements, and discuss the influence realism has towards this genre. This practice-based research and the understanding of these genres are implemented through the progression or outcome of an artefact(s). The theoretical outcome of this research depicts the understanding and the factors of hyperrealism, as this movement inherits both realism and expressive storytelling. The final rendered artefact(s) convey these ideas and their elements in terms of perceptual realism, visual metaphors and photorealistic imagery.

Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of university or other institution of higher learning.

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Definitions

(Table I) *Definitions.*

CG	Computer Graphics. Artificial images created through computer applications.
CGI	Computer Generated Imagery. Images created through computer applications to create artificial content. CGI usually refers to the images created through 3D programs used for special effects in film and television.
2D	Two-Dimensional Space. A space in which only applies up, down, left and right directions. In computer graphics, the X-axis is left and right, and the Y-axis is up and down.
3D	Three-Dimensional Space. A space in which applies depth in addition to a Two-Dimensional Space. In computer graphic programs, 3D is represented by a third axis. The Z-axis adds depth to the 2D plane of X and Y.
FPS	Frames Per Second. A video consists of a sequences of images that are presented within a second. This creates the illusion of movement, the images are therefore animated. FPS states the amount of frames that are being shown within a second. Films are usually 24fps, but can also be 30fps, 48fps, 50fps and 60fps.
HFR	High Frame Rate. 24fps is the standard frame rate for videos and anything above 48fps is a HFR. This is because at a frame rate of 48fps, the motion in a video can start to appear smooth.
Stereoscopic 3D	An image that appears to give the effect of 3D by adding depth into the equation, but in reality, it is still 2D. A technological innovation that adds the perception of depth on a 2D image.
VR	Virtual Reality. A piece of technology that allows us to interact with virtual content and worlds. For example, you can become the character of a video in

	first person perspective and view the virtual world just as one would in the real world.
Photorealism	A movement in which comprises of creating images that resemble a photograph. An artificial image that is indistinguishable from the real scene.
Hyperrealism	An advancement of photorealism. Whilst maintaining the realistic feel of an image, hyperreal imaging would be to add an extra bit of sensation to the image. An enhanced perception towards the image.
RND	Research and Development. An approach towards research, commonly used by firms or individuals in order to create new and improved products or processes.

Introduction

The cinematic world is growing as an industry and it seems that an increasing number of filmmakers are adapting to the world of Computer Generated Imagery (CGI). Technology has drastically improved over the years, giving practitioners more computer power and enabling them to employ methods that are highly efficient and low-cost. In earlier times, the film industry would utilize physical methods to create inhuman characters and other unworldly shots, but now filmmakers can depend on CGI to accomplish those tasks.

The visual effects industry is advancing as the technological world advances. Earlier times of the digital era, computer power and technology were limited; this resulted in generating inaccurate results, such as smooth surfaces, you will see polished wood that is as smooth as glass (Joon, 2010). In current times, due to technological advancements, visual effects has taken a huge leap towards life-like imagery. Photorealism is a movement that inherits the element of realism. The idea behind photorealism is that the visual representation of a character, idea or location is to make it seem as if it was produced through photography (Joon, 2010). In addition, it seems that hyperrealism is a form of advancement to photorealism; a similar movement to photorealism, except it is originally known to be a style of painting in which it conveys sensory and sensational information (Lerena, 2013). This component of sensory and sensational data perceived by the viewer brings forth the concept of perceptual realism. Perception seems

to play an important role within hyperrealism, as its purpose is to generate an emotional response, a sensation that reflects or responds to the image (Lerena, 2013).

Another factor to hyperrealism is immersion; it is the experience of feeling involved. Immersion is a component of film making that has been explored through Stereoscopic 3D and High Frame Rate (HFR) (Michelle, Davis, Hight, & Hardy, 2017). Stereoscopic 3D enables the viewer to experience a film that simulates depth on a 2D image, resulting in an effect that simulates 3D space. HFR is a technique that involves increasing the frame rate of a video to a certain extent in which results in smoother motion. Whilst, Stereoscopic 3D and HFR focus on immersive experiences on a 2D plane, Virtual Reality (VR) is a piece of technology that enables the viewer to experience a virtual world in 3D space. This immersive technology is commonly used for video games but is also a cinematic storytelling gadget. Technology has been shaping the cinematic universe since the silent time and stereoscopic 3D, HFR, and VR are some of the innovations of this time that are becoming known.

Analogical juxtaposition is a specific method of storytelling accomplished through visual metaphors (Visual Metaphors in Film, 2018). This technique refers to subtle and indirect messages conveyed through an image or a scene, except it leaves it to the viewer to interpret these messages. The non-anthropomorphic character within the narrative shown in *Table II*, is a newborn soul established through a flame, it revolves around visual metaphors with the support of scenic attributes. This flame (character) is a fluid simulation generated through the software Houdini FX. This software enables the practitioner to control the flame to specific standards, allowing the inheritance of perceptual cues, expressive storytelling and the control of aesthetics.

Understanding the factors of hyperrealism, such as photorealism, perception and expressive storytelling, supports this study's creation of non-anthropomorphic artefact. The application of these concepts convey subtle traits of hyperrealism produced in the form of a short film and lays out the foundation that narratives need to be a complex network of mental spaces which merge together to reach a final mental representation (Alonso, Molina, & Porto, 2013).

(Table II) *Narrative.*

Act I

A post-apocalyptic setting. The scene is taking place in a old abandoned house. There is an exposed wire, in the damaged ceiling. Water droplets fall through the roof onto this exposed wire. Causing a short-circuit and sparks. The spark particles fall into a vase sitting on a desk in the room below. The vase seems to have a glowing portal-like light emitting from the hole. The sparks that fell into the hole caused a bit irretation and lead to the light exploding. The vase seems to still be intact. Out shoots a fireball. It ricochets of the ceiling and lands on the table to a hault. The flame goes out and reveals that it is a black-spherical mass. The ball of mass starts to wriggle. It seems to be alive, a sort of entity (life form). As the entity suddenly jumps and shoots up, its flame is relit.

Act II

Entity slowly descends back down to the desk. Shows a little shiver. Looks confused. It start to linger, looking around at all the object that surround it. As it travels across the desk, it comes across a lamp. It travels up the lamp and carefully looks at everything, as if it is seeing it for the first time. It travels back down and notices a reflective surface sitting on the desk, a phone. Entity is staring down at the phone taking a first glimpse at itself. A calm emitting flame looks right back. It looks up and over the desk, and notcies there is so much more in the room. As it glances over and spectates the contents in the distance, it travel across the desk and eventually takes a dive down to the floor. It continues to wander. As it explores the rest of the room it comes across a glow of light, an incandescence. It stares at it from a distance and eventually shoots towards it. It seems to be the same glow of light that was previously seen in the vase, except it was in the crack on the floor. Entity observes it and takes a leap into it.

Act III

Instantaneously, Entity shoots right back out. It is now shooting around and across the room as if it is in pain. It eventually flies into the next room. After a few more seconds of bouncing around, Entity blindly enter another glow of light placed around the bottom of the wall. This time Entity does not return.

To be continued…

Literature Review

Photorealism

Photorealism can be defined as visual representations of a situation or location so that it looks as though it was produced through photography or, in reagrds to this research, videography (Joon, 2010). It is an art form used by many artists, traditional and digital. Whereas, hyperrealism is known to be an advancement of photorealism, a style of painting which seeks a perfection of resolution and to achieve a hypnotic sense of objective presence (Lerena, 2013).

Visual Effects is one of the many realms of art that has adapted to the photorealistic medium. As of today, distinguishing computer-generated imagery (CGI) from live action footage has become difficult due to this medium. It has been noted, “the line between real and not real will become more and more blurred” (Prince, 1996, p. 31). This statement was given in 1994, and was not wrong. An art historian named Norman Bryson (1983), mentions that one of the reasons behind this progression is because we as artists continue to challenge ourselves and surpass “ones predecessor’s skills and cast the other into eclipse,” which “brings the talent of the newer artist into the forefront for the next challenge” (Giralt, 2017, p. 12). This is one of the many reasons of how visual effects has developed over the years, from the silent period to this day.

To understand realism within CGI, Joon (2010) engaged in a research project to understand the principles of creating photorealistic CGI. In the field of visual effects and in conjunction to photorealism, principles are a set of rules or techniques that are important to help accomplish a completed piece. Joon (2010) lists an extensive amount of principles along with detailed definitions. *Table III* starts with the factors of showing detail. *Table IV* then covers the elements of light, which are applicable to 3D programs. Lastly, a few other elements that help enhance the result are depth of field, motion blur, basic design understanding, lighting and color temperature, shadow, the rule of thirds, and off-screen space (Joon, 2010). Overwhelmingly, these are the principles Joon (2010) considers to be of help, to create the illusion of photorealism.

(Table III) *Principles: The factors of showing detail.* (Joon, 2010, pp. 18-19)

Principles	Definitions
Clutter and Chaos	Not everything is perfect, objects in the scene need to angle slightly off or be arranged in a specific way. Every surface has defects, may it be dirt, dust or dents. An environment must describe the natural state of living.
Personality and Expectations	People create their environments. Everyone or every creature has a distinct personality that they reflect in their environment. They have a particular way of doing things. Dedicate some time in understanding the creators of the scene; it can be completely chaotic, sloppy or very clean.
Believability	The objects and surfaces in a scene must be recognizable to be believable. The surface and the objects in a scene need to makes sense.
Surface Texture	All real-world object have surface texture. In fact, the proper term for texture is the roughness or smoothness of the object surface. It is the surface attribute that you can feel, all objects have some form of surface texture. A common problem with 3D objects are that their surface is usually too smooth. This just is not realistic.
Specularity	Specularity is the reflection of the light source on the object surface. Specularity is one of the important aspects of photoreal 3D. Without specularity, object would appear dull, soft and flat. Specularity and surface texture work together to simulate real-world surfaces. For example, plastic has rough surface texture. When specularity is applied, it adds specular highlights to the tops of the surface bumps. This gives the plastic surface bumps a 3D feel and give you a visual understanding of the hardness.
Dirt, Dust and Rust	Dirt, Dust and rust are very important aspects of an object surface, which is also referred to as Aging. Almost every surface is actually never clean, there will always be a bit of dust or dirt, even if a little. Apart from that aging is a

	critical aspect of all objects in reality. Explore the scene to find out what kind of aging to add, where it is coming from and how it is being spread.
Flaws, Scratches and Dings	Flawless surfaces can make an object look artificial. Even brand new objects have occasional subtle flaws. Without flaws and object can look too perfect. The flaws in some cases need to reflect the nature of the scene.
Beveled Edges	Nearly every real-world object that is manufactured has beveled edges. Sometimes it is just too small to see. This can become an issue with the absence of specularity. There will be very subtle specular lights highlights on the beveled edges. These highlights become very noticeable when the object is animated. Without them, the 3D object will seem artificial.
Object Material Depth	This refers to the physical depth of material. All real-world objects have depth. There are only a few objects that have a depth that would resemble the thickness of a single polygon, which is paper. This problem is mainly seen in character clothing, where the clothing resembles paper hanging off a model.
Radiosity	Specularity and Radiosity are the principles account for all of the lighting in a scene, which generally can be referred to as Global Illumination.

(Table IV) *Principles: Elements of Light* (Joon, 2010, pp. 19-20)

Type of Light	**Definitions**
Global Illumination	Global Illumination is a term to describe a scene that is hit by direct, bounced, reflected and refracted light, as in real world situations. This type of light takes into consideration of light reflecting off all surfaces in the scene (indirect illumination) in addition to light coming directly from light sources (direct illumination).

Dome lighting	In CG, Dome Lighting is the process of setting up a skylight, or multiple lights in a spherical or hemi-spherical way.
Ambient Occlusion	Ambient Occlusion works by determining the proximity of objects to calculate dark areas between them.
Radiosity	Radiosity calculates the intensity of all surfaces in the scene rather than just the ones traces back to the screen. It works by simulating heat transfer between surfaces.
Raytracing	Raytracing is a Global Illumination based rendering method. It traces rays of light from the camera back through the image plane into the scene. Then the rays are tested against all objects in the scene to determine if they intersect any objects. If the rays misses all objects, then that pixel is shaded the background color. Raytracing helps create accurate shadow casting, surface reflections, transparent objects, interior reflections, complex illuminations and realistic material.
Caustics	Caustics is created when light is reflected off a specular or reflective surface, or focused through a refractive surface, so that it indirectly illuminated other surfaces with focused light patterns.
Color Bleeding	This is the transfer of color between nearby objects, caused by the colored reflection or refraction of indirect light.

Kevin Mack and Chris Voellmann (Prince, 1996), two CGI artists, point out that light, texture and movement are the most important principles to manipulate in order to create synthetic reality looking real as possible (Prince, 1996). While all three practitioners mention the important elements for representing realism through CGI, they did not mention hyperrealism or explain any factors of this movement, as if it was not important. Prince (1996) states that, the most important step, above all, is to

be able to show perceptual cues. Perception is a major factor within hyperrealism and it is what notably separates it from photorealism. Photorealism explained in this section and the extensive lists of principles are all factors that contribute to the creation of realistic CGI. This thesis draws heavily on these principles in order to achieve a genuine, photorealistic flame within a completely CG scene.

Hyperrealism & Perception

An important aspect of hyperrealism is perception. Hyperrealism, or in this case, perceptual realism is a perfection of resolution, a hypnotic sense of objective presence. The movement's purpose is to make the real and the illusory indiscernible. Some also say the art is more realistic than photography (Lerena, 2013).

Interestingly, Prince (1996), indirectly, supports this claim. The many practitioners Prince (1996) interviewed, majority of them referred to photograph as a "referent" (Prince, 1996). Implying that live-action video is also a form of referent, since a camera is just an instrument in which it captures a "succession of happenings" (Giralt, 2017). The camera is a poor instrument compared to the human eye, it is a "lossy" instrument that fails to capture the full range of luminosity in a scene or environment (Prince, 2011). Giralt (2017) also makes a similar remark, the human eye sees an object, and it sees a substance because its sight is animated with the person's intelligence (Giralt, 2017). In saying this, the intellect of a human mind, the artist, is what projects perception into an image. The camera captures a succession of happenings, and then a VFX artist's job would be to connect the image to the viewer and the viewer to the image. When viewing a hyperreal image, the perception involved is described to be a sensory and a sensation (Lerena, 2013). The link between the solitude of the artwork and human community is a matter of transformed sensation (Lerena, 2013). The transformed sensation that is baldly stated emphasizes on human understanding, perception taking a form of sensory data onto an image. The objects and small perceptual cues of detail, connect the audience to the image and is an extremely powerful means of "gluing" together synthetic and live action scenes (Prince, 1996).

Another aspect of perception is depicted in Peter Jackson's films, The Hobbit (2012) series. Michelle et al (2017) explain how the combination of high frame rate (HFR), stereoscopic 3D and CGI was used to improve perception and immersion for viewers, to give a "groundbreaking, hyperrealistic" experience. The HFR, forty-eight frames per second (fps) approach allows the film to appear smoother, whilst standard films are generally twenty-four fps (Michelle, Davis, Hight, & Hardy, 2017). Linking back to, a "succession of happenings" (Giralt, 2017), which is being referred to frames per second. It is a series of images shown

in a sequence, within a second, to create the illusion of a moving image. Stereoscopic 3D is another innovation that gives the illusion of depth perception. The way this works is that a stereoscopic image must be separated so that only the right eye sees one image and only the left eye sees the other image. The two images are fused by the brain into a single 3D picture (Block, 2013). However, the paradoxical response from the viewers was described to be immersive but also unconvincing and distracting (Michelle, Davis, Hight, & Hardy, 2017). Overall, perception seems to play a major role in convincing the audience of realistic CGI, it is the small details the artist applies and the addition of human sensory elements that can sell the audience. In regards to HFR and Stereoscopic 3D, these are the concepts introduced to the film industry to improve perceptual cues of hyperrealism, except this combination did not seem to please the audience.

Immersion

Immersion, the experience of feeling involved. Trickery, being fooled to believe it is real. The combination of these terms reflect the idea of stereoscopic 3D. As stated previously, The Hobbit (2012) series consisted of HFR, stereoscopic 3D and CGI to improve the immersive experience. A portion of the responses were loyal to Tolkeins's (1937), the author of the books, original work and Peter Jackson's, the director, Lord of the Rings films. The Hobbit (2012) had complicated the audience's reaction (Michelle, Davis, Hight, & Hardy, 2017). The forty-eight fps approach was in hopes to eliminate the motion blurring and to ease other troubling visual artefacts caused by dimness, ghosting and flickering. Michelle et al (2017) state that the director was confident that, in combination, HFR and Stereoscopic 3D would pull viewers out of their seats, it would be life-like than ever before (Michelle, Davis, Hight, & Hardy, 2017).

Motion blur is a principle that helps create the illusion of speed, "movement among the objects in the scene" (Joon, 2010, p. 22). The illusion of speed would definitely be absent in The Hobbit (2012) series, as forty-eight fps had eliminated motion blurring. The visual smoothness of these films contradict the statement, "I want randomness and irregularity that seem truly natural" (Giralt, 2017, p. 12). Also, "the visual harmony of things is dictated not, as consumer society would have us believe, by perfection, but by imperfection, idiosyncrasy and unpredictability" (Sparnaay, 2002, p. 46). Lastly, "the trademark of flaw of most 3D images is lack of detail" (Joon, 2010, p. 23). All statements above applying the same rule, perfection is derived from the imperfections, ironically The Hobbit (2012) films oppose to this.

In other cases, low quality sound and visuals have a negative effect on the mind. The neural activity of the human mind seems to show fatigue, as visual images and sound quality were degraded (Arndt, 2016). Similarly, it had the same effect on the participants viewing the Stereoscopic 3D film. The quality was not degraded, but it was enhanced in motion by two times the normal runtime of twenty-four fps, displaying an unnatural smoothness in every movement and motion. Adding the illusion of 3D on top of those elements, confused the viewers on a subatomic level. This evidential insight in neural activity supports the viewer's response of unconvincing and distracting, (Michelle, Davis, Hight, & Hardy, 2017) which may justify the few viewers that were feeling motion sickness. The immersive cinema is an experimental concept striving to step into the cinematic world. The notion of hyperrealistic experiences with HFR and Stereoscopic 3D is an interesting step forward, but it has been proven to be very unnatural, it does not include the small imperfections, hence the natural movements of this world.

The Digital Age & Technology

The digital realm has improved drastically over the years, cinema has merged sound and moving images to depict our imaginary worlds. The more convincing these imaginary worlds seem the more immersive the spaces of story and image become (Prince, 2011). Technology has been shaping the cinematic world ever since the silent time. The cinematic world has had a "history of innovations that tend towards higher and higher degree of immersion" (Prince, 2011, p. 183).

Virtual Reality (VR) has emerged, it expands the possibilities for narrative development and the role of the spectator (Dooley, 2018). VR would involve the viewer appearing in live action virtual worlds made by 360 degrees cameras, it can also be an immersive form of playing video games. VR can have varying levels and combinations of multimodal sensory input, allowing audio, haptic, olfactory and motion to be experienced simultaneously (Wilson & Soranzo, 2015). Through this technology, a character's vision is perceived through first person or third person perspectives. The limitation of this product within cinema is that VR typically features a construction of a single three-dimensional long take, whereas VR in video games, the player is in control of the movements within the 3D space. There are no edited collections of close-ups, mid and long shots, as VR is an interactive medium where you, as the viewer, control the viewport. In addition, it seems that VR also carries the negative responses the viewers and participants had stated about HFR and Stereoscopic 3D regarding The Hobbit (2012) film series. There are VR-induced side effects that are often a general feeling of malaise or motion sickness (Wilson & Soranzo, 2015). As stated

previously, neural activity of the mind shows fatigue due to the change in visual images and sounds, specifically degradation, and the impact of HFR and Stereoscopic 3D had on viewers prove that unorthodox methods prove to have negative impact on some viewers.

The technology as of today, compared to the technology during the emergence of digital cinema has developed quite a bit. Immersion and perceptual realism within cinema has developed, as new and improved sound and image quality "instruments" have emerged. Sound was one of the first components to go digital and now sound is offered in highly immersive formats including Dolby TruHD, DTS-HD and LPCM (Prince, 2011).These sound qualities support eight-channel audio system, which means, eight speakers would each play its own unique soundtrack based on the scene of a film. This will heighten the immersive experience, as it would seem as the scene is taking place in the room. Overall, the point here is that technology has always played an important role in shaping the cinema and the cinematic experience. The limitations of cinema, immersion and perceptual realism will continue to change, as technology is always developing.

Expressive Storytelling

Juxtaposition

A film communicates a narrative, through visuals, vocals and music. The combination of these three channels have become the essence of digital storytelling (Alonso, Molina, & Porto, 2013). A specific component of visual storytelling focuses on visual metaphors, also known as analogical juxtaposition. A visual metaphor is an idea, a feeling or a story represented in an object (Visual Metaphors in Film, 2018) It is an indirect message placed within a scene, leaving it to the viewer to be discovered. It is believed that narratives must be more than a succession of temporal events, narratives need to be a complex network of mental spaces which combine or blend together to reach a final mental representation (Alonso, Molina, & Porto, 2013). Soviet filmmakers, Lev Kuleshov, Vsevolod Pudovkin and Sergei Eisenstein of the early 1900s, originally explored this concept (Loftin, 2018). Kuleshov's (2009) experiment consisted of sequential shots showing a subject followed by a character (Kuleshov, 2009). The experiment's purpose was to observe the many viewer's interpretations of the video, which had no sound, vocals or context between each shot (image). This, now known as the,"Kuleshov Effect" demonstrated the essence of juxtaposition. The subtle visual metaphors that are present, tell an underlying story that leaves it solely to the viewer to discover the truth.

Anthropomorphism

Anthropomorphism is an attributes in which it can add characteristics, rational thought, and conscious feelings to abstract concepts, material states or objects. The purpose of this technique is to encourage viewers to see the human in the non-human subjects (Esch, et al., 2019). Thus, the relation between the object and the viewer has earned some sense of trust, due to common attributes. The character, represented as fire, for this research, is playing the role of a newborn soul. The contradicting factor of this character is that anthropomorphic qualities should be depicted from it, except these human-like qualities will not be, to the most part, consciously present. The inclusion of the previously mentioned visual metaphors will portray most of these anthropomorphic qualities through color, juxtaposition and the placement of specific artefacts within the scene. Linking back to previously mentioned topics, hyperrealism and perceptual realism are components of this study, that encompass these qualities to truly define its purpose of visual, “sensory and sensational” data.

Dynamic Simulations

Dynamic Simulations have made significant progress due to both rapid increase of computing power and the development of more efficient algorithms. In computer graphics, fluid simulation plays the key visual effects in animation and special effects. The technique of fluid simulation can be used to reproduce gaseous smoke, fire, water, and highly viscous liquid, etc. (Ren, et al., 2018). Houdini FX, a SideFX visual effects software, offers a range of tools to create many fluid dynamics. It also gives the user access to the properties of the dynamics, allowing full control over the simulation. In particular, the manipulation of fire allows the user to create the flame’s shape, color and intensity as desired. The software gives access to the many elements that helps influence the flame a specific way, this includes natural forces and attributes like wind, turbulence, dissipation, viscosity, amount of fuel, etc. The proposed fire character, in context to the scene, can symbolize a certain idea. Fire has the ability to convey life, a sense of well-being, love and warmth and lastly, death (Manopriya, 2015). The symbolism of a flame would require context, as the symbolic gesture of a flame alone can create confusion. The environment in which will provide the context will be constructed in Autodesk Maya. Maya is a 3D software allowing to create complicated structures, 3D models and animations. Maya and Houdini are 3D programs that have the ability to go back and forth with 3D data, allowing seamless integrations of scenes and fire simulations. These 3D programs supply the practitioner with the necessary control to inherit the elements of visual perception, sensory, sensational and metaphorical (juxtaposition) data into a scene.

Methodology

This study is driven by the main research question "*How can fire be used as the sole expressive element within a short film?*"

In order to manage the scope and extent of this work, the main question has been divided into a number of sub-questions.

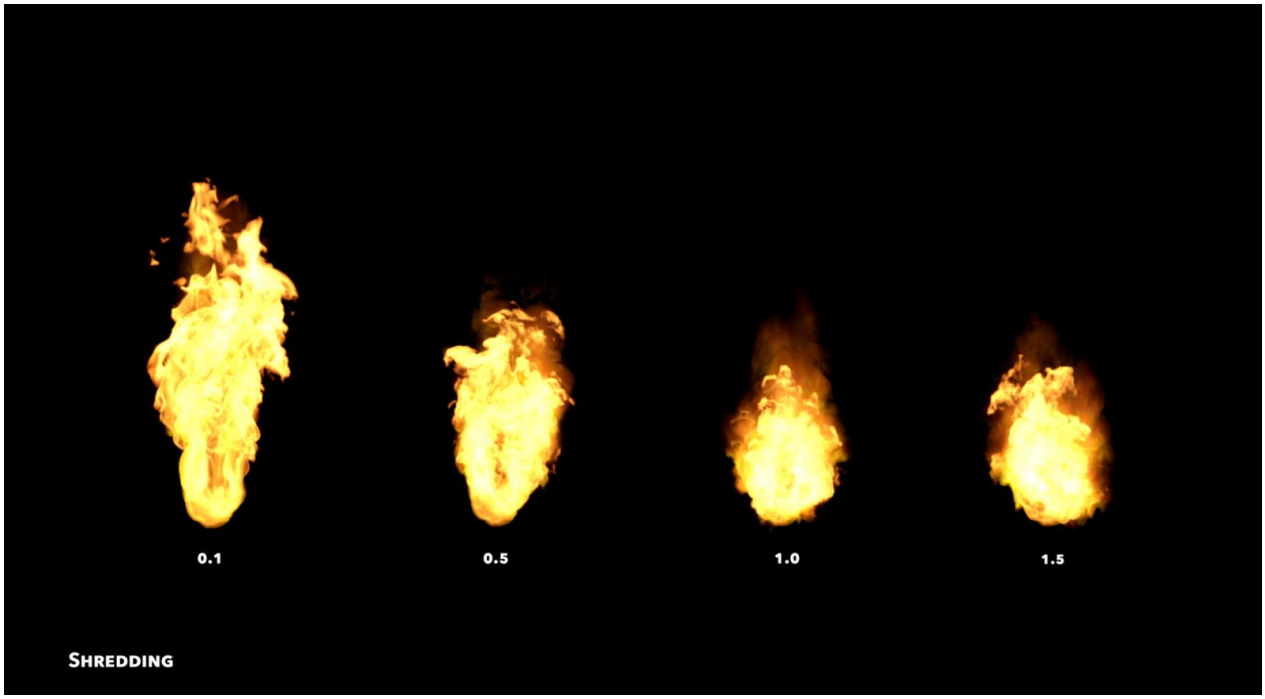
- *How can the exclusion of anthropomorphism on a non-human character communicate an idea?*
- *To what extent can a flame be expressive, whilst maintaining the contradicting factor of realism?*
- *What are some methods of influencing an underlying message within a visual narrative?*

The research explores important aspects of digital storytelling that can be achieved through visual effects alone. Hyperrealism is an art style that reflects an idea completely through the means of visual interpretations, which is essentially conveyed through subtle cues (Nicholls, 2017). A flame is the subject of this research and a narrative is to be implemented through means of subtle cues of the character and/or the scene. This study focuses on understanding the importance of digital storytelling within the field of visual effects, especially how the concept of hyperrealism can influence the viewer's perception. This study is to look into how visual storytelling techniques can improve the complexity of a narrative, reflecting the complexity of the real world and how the intellectual mind of a viewer can create a judgement based on these small cues. This can possibly reveal new methods of visual storytelling and add to the field of visual effects and filmmaking. The absence of anthropomorphism is to support the idea of a message being conveyed completely through the means of subtle cues, rather than having obvious human traits.

Practice-based research is a methodology utilized to gain new knowledge through practice, and result in in an artefact as the creative outcome of the research. The data recorded through this approach is best understood through a critical analysis that would reference these artefacts (Candy, 2006). This type of research is an approach that has yet to reach a settled status, an accurate definition, despite its presence in academic texts for over 35 years (Candy & Edmonds, 2018). To eliminate confusion, amongst other similar fields that utilize this research method, Candy and Edmonds (2018) mention, for example, that in the field of design research the emphasis is on understanding the work process and how to improve on it. Whereas, this particular thesis, the artefact plays a vital role in the new understandings (Candy & Edmonds, 2018).

The proposed approach to a practice-based research is to be conducted through an iterative and incremental cycle. The stages within each large cycle of activities (idea-generation, investigation, analysis, evaluation, etc.) involve many iterations, during which the practitioner identifies, which of the many outcomes from the task in hand are useful or best discarded (Candy & Edmonds, 2018). This iterative and incremental research cycle will be conducted within the software, Houdini FX. This is a 3D visual effects software comprising of many tools that aid in achieving realistic CG dynamics. The creation and development of an artefact is crucial, and the insights from making, reflecting and evaluating can possibly feed back directly into the final artefact itself (Candy & Edmonds, 2018).

An example of the iterative and incremental approach shown in *Figure I*, shows the impact of the shredding parameter has had on the shape of the flame. The scale values below each flame reflects the change in shape, hence the increase in shredding. In the field of animation and visual effects, many practitioners use the term Research and Development (RnD). RnD is quite similar to the iterative and increment cycle, if not the same. It is commonly used to describe activities undertaken by firms or individuals in order to create new and improved products or processes (Hall, 2006).



(Figure I) *Shredding parameter test.*

To manipulate fire, the selected software, Houdini FX, will assist in this process. In progression, the many videos and images accumulated will provide reference to assist the practitioner in the final simulation. These tests will run in an empty Houdini scene and rendered with adequate quality. The degradation in quality is because these simulations and renders can take a lot time to process, so these tests are not high quality renders. At this point of the process, an adequate understanding of fire dynamics and rendering is obtained. The original knowledge obtained through this investigation may or may not be a contribution of new knowledge to the field as it is, in a sense, directed towards the individual's particular goals of the time (Candy, 2006).

As soon as the testing and trials has reached an impasse, the creation of the scene will then commence. Autodesk Maya, will be the core 3D modeling and animating software. Houdini FX, the core dynamics software, will work in conjunction with Maya to create the final rendered artefact.

The artefact involves a character that is expressed through fire dynamics, certain actions imply certain moods. A shake or shiver would release fire ember or smoke, based on the irritation level of the character. There are a few 3D models in each scene, conveying an underlying story as well as linking directly to the main narrative. This includes, a certain object placed in the background, an arrangement of certain objects, or a reflection that directs the viewer to certain thoughts (Lerena, 2013). These visual metaphors are spread across each scene and leaves it to the viewer to decode. Perception, visual metaphors and the photorealistic approach all interconnect to help convey a story of a non-anthropomorphic character. Reflecting the previously mentioned statement, that narratives need to be a complex network of mental space, which combine to reach a final mental representation (Alonso, Molina, & Porto, 2013).

Software & Hardware

Houdini FX (SideFX)

Houdini FX is a 3D platform software, essentially designed for films, television and games asset production. Houdini's core feature, 3D dynamics, allows the user to create realistic fluids, particles effects, destructive environments, fur and most importantly fire. Pyro FX enables the user to create realistic fire with the ability to manipulate the flame as desired. This software also has standard rendering engine called Mantra, this will enable the rendering of the pyro simulation into an image

sequence, which can then be edited in video editing software. This is the core software for this research and the discussion will revolve around Pyro FX and the flame generated from this software.

Autodesk Maya

Autodesk Maya is a 3D animation, modeling and rendering software provides an integrated, powerful toolset. It is used for animation, environments, motion graphics, virtual reality and character creation. This software will essentially assist in creating the scene based on the narrative. The 3D models, cameras and lights will all be set up in this program, and the character's general movement will also be animated using this software. This software will work in conjunction to Houdini, through the process it will involve transferring assets to one another, in which will be mentioned through the development of the flame.

Hardware

These two 3D programs require a lot of computing power and *Table V* shows the computers that are available for this research, and their hardware specifications. This is a fluid dynamics research, hence fire, and SideFX recommends 64 GB of RAM for fluid simulations (SideFX, 2019). The available computers only have 32 GB of RAM, this has caused a few issues. The explanation of this issue is discussed the *Simulation I* section.

(Table V) *Available Computers.*

Computers	Computer I	Computer II	Computer III (AUT)
Operating System (OS)	Windows 10 Proffesional	Windows 10 Professional	Windows 10
Central Processing Unit (CPU)	Intel Core i7700K CPU Quad-Core Processor @ 4.20 GHz, x64-based processor	AMD Ryzen Threadripper 1950X 16-Core Processor @ 3.40 GHz, x64-based processor	
Graphics Processing Unit (GPU)	NVidia Geforce GTX 1080, 8 GB VRAM	NVidia Geforce GTX 750Ti, 2 GB VRAM	NVidia Geforce GTX 1080, 8 GB VRAM
Random Access Memory (RAM)	32 GB	32 GB	32GB
Disk Space	1 TB SSD, 1 TB HDD and 4 TB HDD	250 GB SSD	

Additional Software

Substance Painter and Substance Designer (Allegorithmic)

Substance Painter and Substance Designer are both 3D texturing software, they provide the essential tools to create and add high quality textures to 3D models. Substance Painter has an interactive approach towards texturing 3D models. This software allows the user to select a brush and directly paint on an imported 3D model as If it was a sculpture in real life. It provides many preloaded brushes and textures, and most importantly the ability to create your own textures from scratch.

Substance Designer is a similar software, except the application of textures is accomplished through a node-based system. This type of system allows the user to add textures, colour and depth data on top of each other to create a final texture map. Each node is adjustable through a provided parameter window, allowing the user to adjust the finer details of the texture. The textures created in these programs are stored and exported in separate texture maps (images), such as color, glossiness and displacement. Each map has it own purpose, which is then imported and applied to the 3D model within the 3D modeling software, which in this case is Maya.

UVLayout (Headus)

UVLayout is stand-alone application for the creation and editing of UV texture coordinates for 3D models. UV mapping is the process of projecting 2D images onto a 3D model's surface and essentially a 3D model's surface mapped out flat, as a 2D image. This software allows the user to create and adjust the UV's of a 3D model with ease, which is then imported back into the modeling software, Maya. Having clean and sorted UV's allows the texturing process to be much easier.

Photoshop (Adobe)

A photo editing software designed to create and manipulate photos. This software assist in editing and tweaking 2D images, with controls such as contrast, color and texture editing, etc. This is not an essential software to have for 3D models, it is useful when required to make a small adjustment.

After Effects and Premiere Pro (Adobe)

After Effects and Premiere Pro are both video editing software. After Effects is focused around creating, editing and manipulating videos or image sequences. It is also the core product in which Motion

Graphics is achieved. This software allows the editing of image sequences that are rendered from 3D programs, such as Maya, and able to enhance and manipulate them, if required.

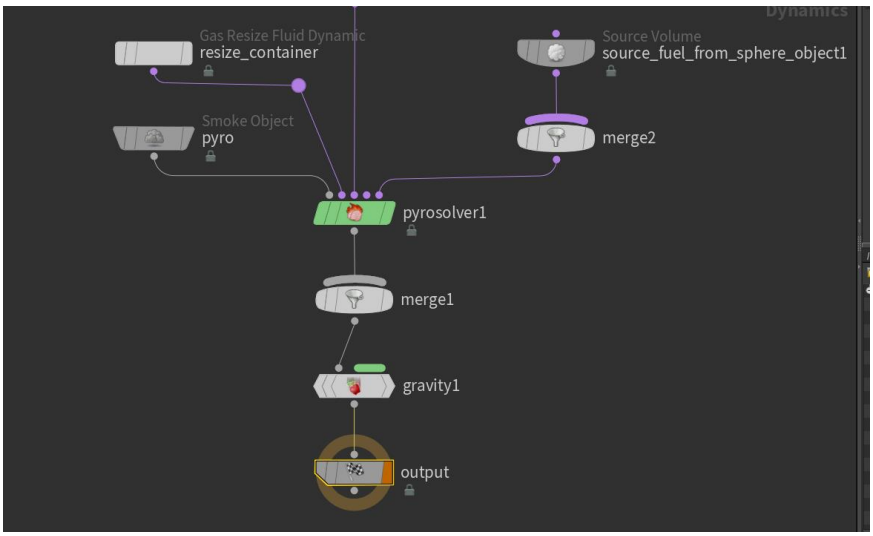
Premiere Pro is essentially a software that enables the user to cut, edit and add sound to videos. It is usually the following software to use in conjunction to After Effects.

Development and Discussion of Artefact

From the chosen research methodology and the established intentions, this part of the thesis will discuss the development and implications of each aspect of the artefact. As stated previously, practice-based research is a methodology intended to gain new knowledge through practice. The discovery of additional information and technical conflicts that have occurred through this process are explained in depth.

Node-based System

Houdini can seem to be a complicated software comprising of many technical methods of achieving a specific outcome. This software is a node-based system in which a network of nodes interconnect, allowing important simulation data to transfer to one another resulting in a simulation. The outcome can completely change in shape and color if a parameter has been tampered with. An example of a network of nodes are shown in *Figure II,* all the nodes that feed into the *pyrosolver1* node, carry data that allows *pyrosolver1* to calculate all the information that it is receiving. One particular data that it is receiving is fuel data, from the *Source Volume* node called *source_fuel_from_sphere_object1.* The *Source Volume* node provides the *pyrosolver1* the location and the amount of fuel the source is generating, allowing *pyrosolver1* to create a flame accordingly. This node-based system is also present in Maya 2018 in particular areas of the software. The node-based system can seem to be a complicated structure but through this practice, it has proven to be a very reliable, allowing the user to control the certain aspect of the process with ease of accessibility. It is important to understand the general operating process, the techniques and important parameters of Houdini that will prove to be useful when generating the final pyro simulation.

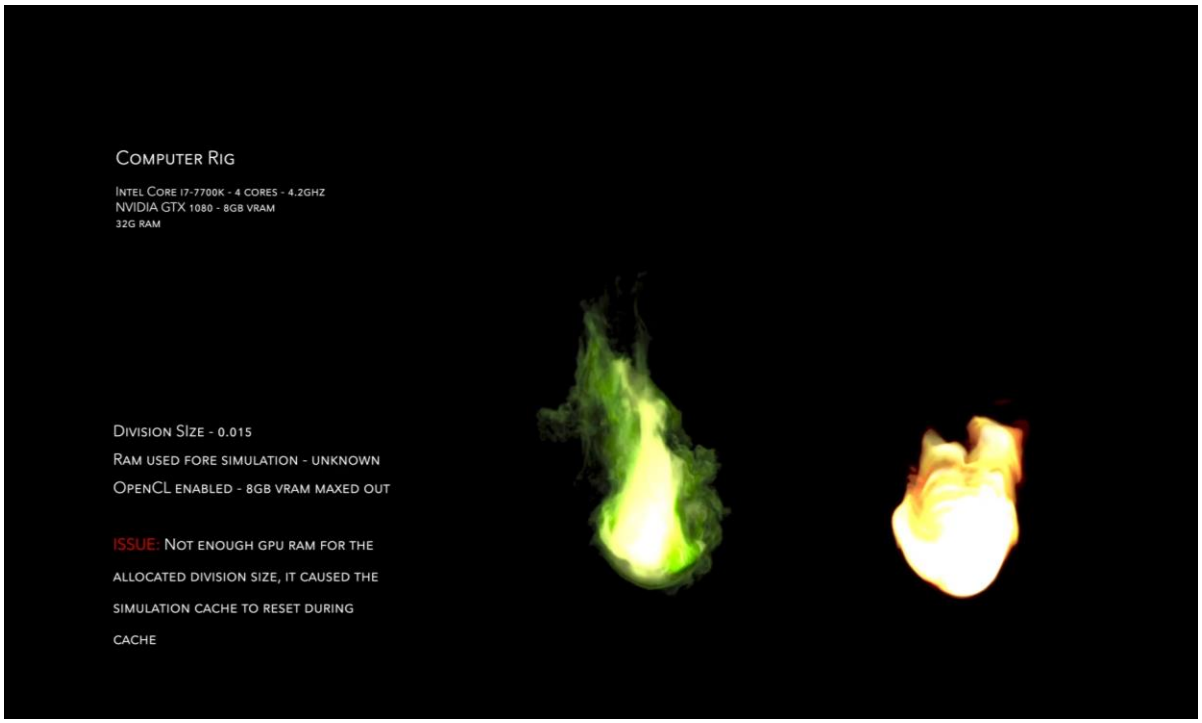


(Figure II) *A network of nodes used for fire simulation (Houdini).*

Simulation I

Houdini's node based system can be intimidating; thankfully, Houdini also includes a shelf of contents within the software. These contents hold easy access to tools and most importantly preloaded node networks that generate a standard node network, almost like a template to initiate the process. The provided preloaded assets have proven to assist the researcher when nodes have been tampered with, unintentionally. Therefore, the provided templates are useful to troubleshoot the issue, especially when the node network consists of many interconnecting nodes. The first attempted simulation, shown in *Figure III*, utilized the available Pyro FX template to help create a generic fire simulation and rendered it with a few adjustments in quality, shape and color.

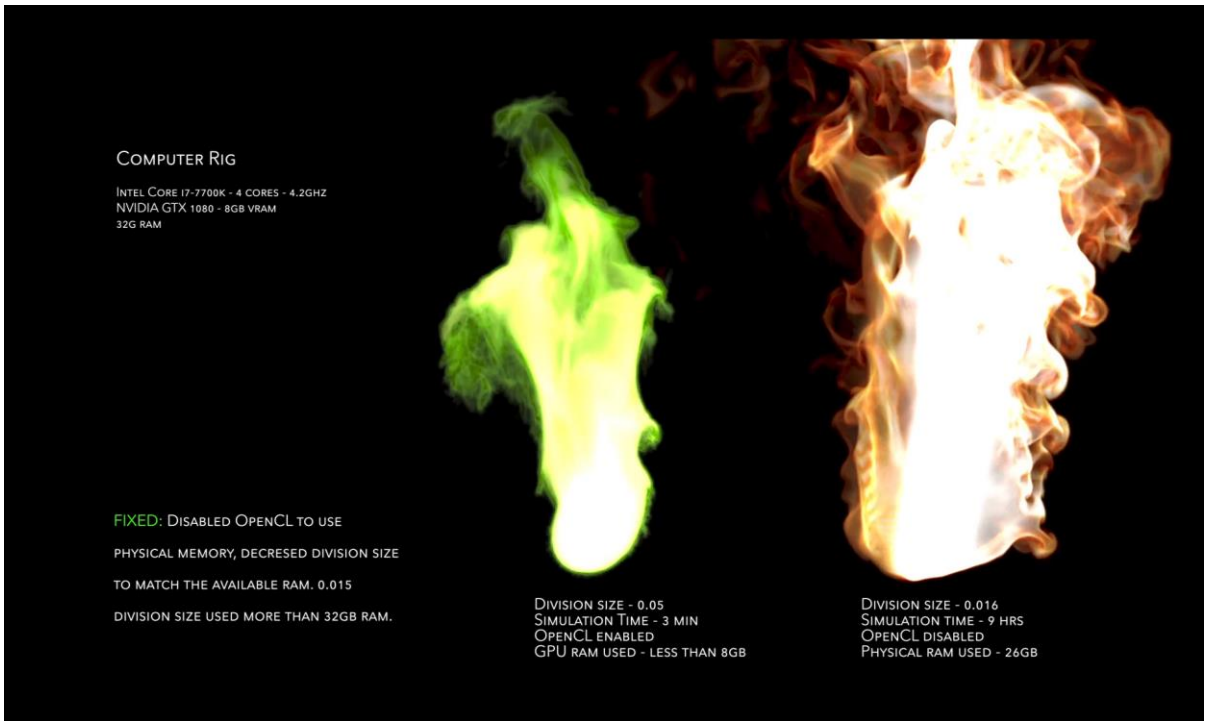
The issue here was that the simulation seemed to reset every few seconds, resulting in a flame that seems to be dying out unnaturally and restarting. The issue was also observed within the simulation cache files. Cache files hold the simulation data in a compressed format (bgeo.sc) stored onto the hard drive in a sequence, according to frame number, allowing ease of workflow without the usage of heavy amounts of computer RAM. The cache files showed a huge drop in file size in the exact moment the flame has shown to die out. This proved there is a loss of simulation data during the caching process.



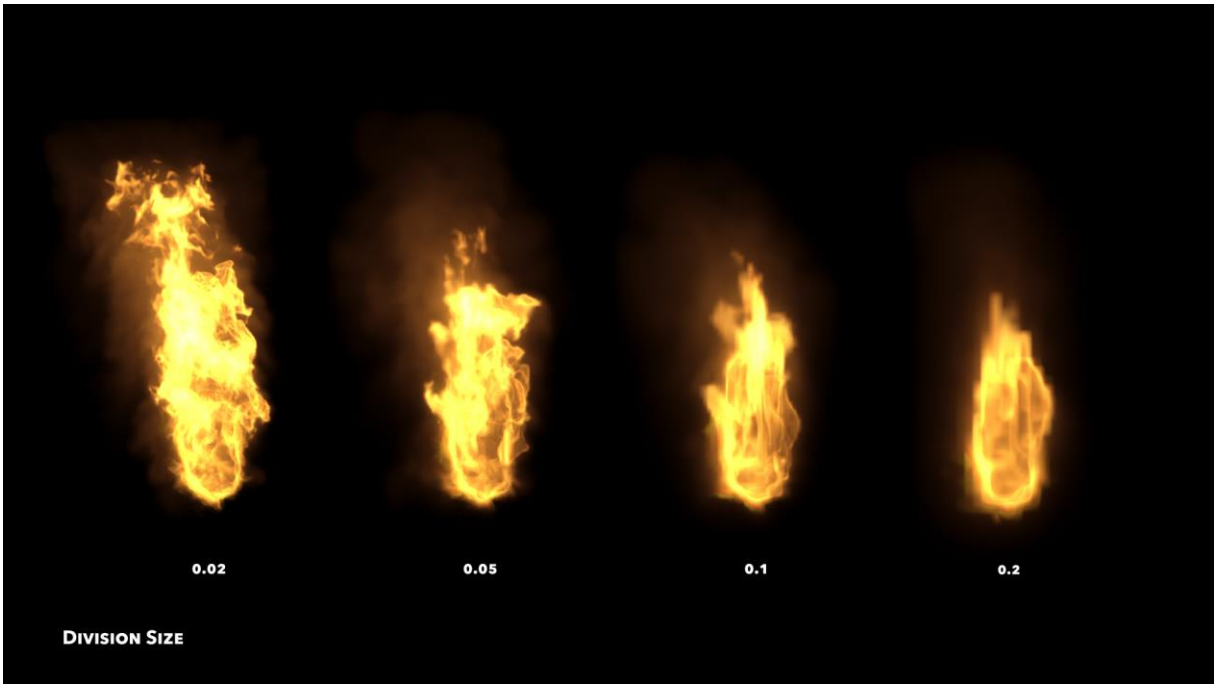
(Figure III) *First attempt at simulating and rendering fire in Houdini.*

The source of the issue was discovered to be present during the caching process. It seems that at those increments of data loss, the GPU's 8 GB of VRAM was not enough. The flames in *Figure III* were simulated using OpenCL, a parameter within Houdini that enables the use of the GPU to speed up the simulation process.

The solution, also stated in *Figure IV*, was discovered once OpenCL was disabled. The red flame shown in *Figure IV* is a successful simulation utilizing 26 GB of the computer's 32 GB physical RAM. This simulation caching process took 9 hours with the division size of 0.016. The division size is what determines the output quality of the flame simulation. *Figure V* shows that a low division size will result in a high quality flame, whilst a higher value will produce a blurry result. This means the simulation that failed was set too high in quality, resulting in the GPU failing through the process. It also explains the prolonged time it took to simulate and the huge amount of RAM it used up. To compare, the green flame in *Figure IV* has a higher division size value, which allowed the simulation to be cached using the GPU. The simulation this time only took 3 minutes and used less than 8 GB of VRAM.



(Figure IV) *The solution to the issue of the first attempt.*



(Figure V) *Division Size Test.*

Simulation II

It is clear that the character, for the proposed narrative, is a flame. The narrative also implies that the character has intelligence, a mind, and the ability to understand and interpret. It has characteristics of a living person, except the narrative does not explain that it is a non-anthropomorphic character. It does not have the physical attributes or appearance of a living creature, such as arms, legs, eyes, mouth, etc., there are only implications. The artefact will not have music or vocals to direct the audience of the narrative, similar to the previously mentioned Kuleshov Effect (Kuleshov, 2009). This experiment excluded two of the three mentioned channels, visual, vocals and music, the three channels that are the essence of digital story telling (Alonso, Molina, & Porto, 2013). In saying this, the character will convey a sense of emotion through the flame itself.

The sense of emotion, within a flame, is portrayed through the many stages, or shapes, a flame can take. Fire can be known to symbolise many ideas, such as warmth, life, anger and destruction (Manopriya, 2015). The many ideas a flame can convey is explained to require context to imply the specific message (Manopriya, 2015). The flame in this narrative is a newborn soul, an innocent life form.

The three stages of fire shown in *Figure VI* reflect the moods the character conveys. The first *Candle Flame* represents the innocence of the character; also, it reflects the newborn soul, which is portrayed through the shape and size of the flame. The *Candle Flame* is designed to imply warmth, calm and innocence. The second flame, *Flame and Smoke,* is the developed and neutral state of the character, except it is has grown, advanced from its initial state of pure innocence. This particular state has details in its flames, encompassing the idea of change. The smoke is unnecessary, but can prove to be useful to imply a change of mood, specifically a sense of anger. The final flame, *Flame + Ember + Smoke,* has ember in addition to the previous flame. The ember can possibly add the idea of aggressiveness or irritation. The flames in *Figure VI* are not absolute states; they are merely a visualization of the types of flames in which the character can morph between to indicate certain moods.

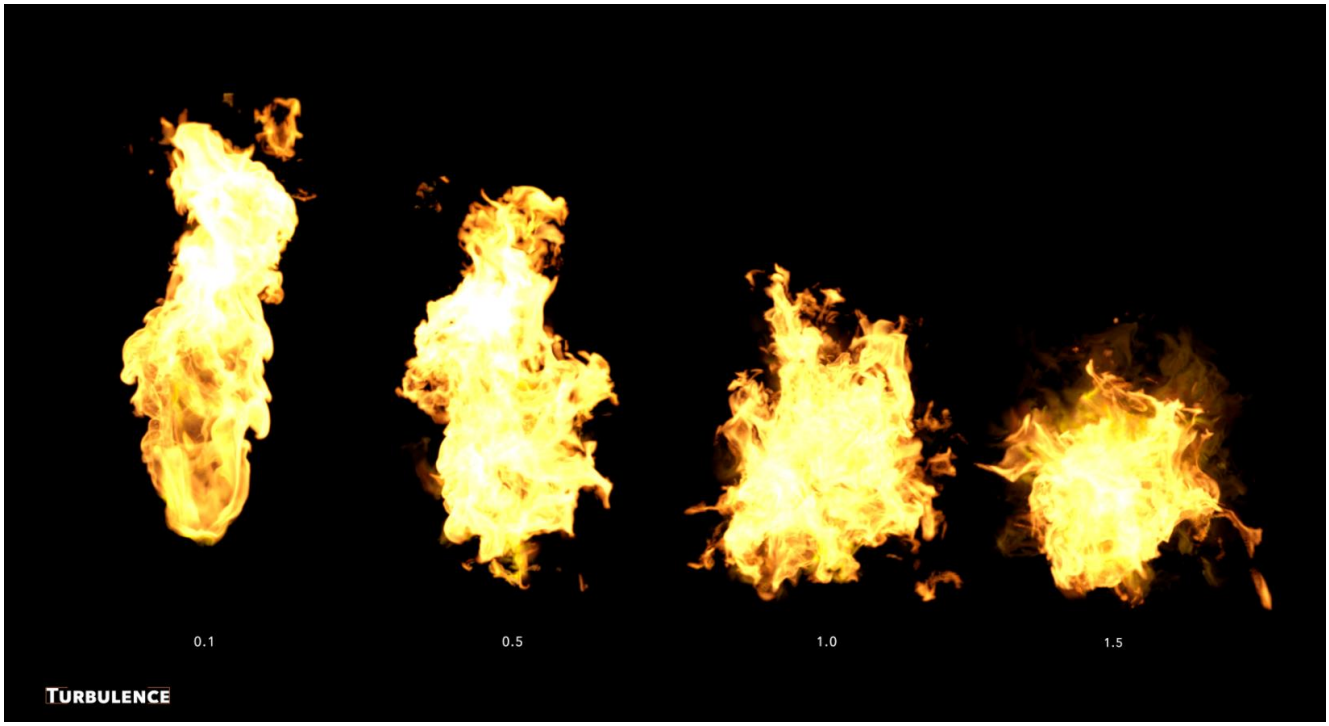
In addition to the technical issue mentioned in *Simulation I,* regarding the heavy usage of RAM, the flames in *Figure VI* are high quality and have been successfully simulated. The division size for these flames, range from 0.015 to 0.020, whilst having OpenCL enabled. This was achieved through the understanding of the *resize_container* node; this node can be seen in *Figure II.* The properties of this node establish the limits and boundaries of the simulation. Through this process, the amount of data

stored onto the hard drive, the RAM usage and caching time had drastically decreased, whilst maintaining a high quality simulation.

(Figure VI) *Each flame represents a state in which the character can morph between.*

Simulation III

As the character is stated to be a non-anthropomorphic life form. There are certain aspects of natural flames that can still be manipulated within Houdini to indicate a type of "sensory" information, subtle it may be. Houdini allows the flame's shape to be manipulated through the application of forces. Turbulence and Shredding has proven to be a few of the important forces, as they can completely change the motion of the flame. *Figure VII* shows the turbulence parameter incrementally increasing therefore changing the overall shape of the flame. The values shown in this example are set to extreme values, as it can act as a reference for future projects. The roughness shown in these flames can initiate the idea of aggressiveness or a similar mood. Whilst decreasing the value can result in a smoother flame, having an effect of opposing aggressiveness.



(Figure VII) *The effects of Turbulence.*

Time scale is another attribute that is important for the simulation of fire. Fire has been known to be a dynamic that can vary in motion speed. For example, the flame on a candle is slow and motionless (Relax&Background, 2016), whereas a house fire can prove to be aggressive and quite abrupt (360 House Fire Demonstration How Quickly Flames Can Spread, 2018). The standard time scale value for Houdini is 1.0, which can work for the flame of a candle. However, an aggressive flame would require the value of up to 1.2 and 1.5, thus increasing the speed of the flame and this has proven to show promising results. This particular parameter has proven to be important; with an incorrect value, it can make the motion of the flame seem unnatural. Keeping this parameter at the right value maintains the realism.

Setting

The flame artefact is to be placed within a post-apocalyptic setting; the reason for this particular setting will be explained soon. Firstly, it is important to understand the underlying story that is absent within the narrative, but is implemented within the artefact itself. The world the character is "born" in is a simulation. Ironically, through the practitioner's perspective, this is in fact true. The character sees the

world to be convincingly real, as it is a replica of the real world. A similar concept of this underlying story has previously been conveyed in the film, The Matrix (1999). Thus, showing the importance of researching the photorealism movement, the visual representation needs to be convincing towards the audience, conveying the idea of the real world. The researched, Kuleshov effect, is implemented within the post-apocalyptic setting. The world itself and a few objects placed in this world imply a sense of negativity, except this is left to viewer to decide to what extent. *Figure VIII* is a shot of the top a desk from within the setting. According to this render, it seems that the principles towards photorealism mentioned by Joon (2010) have to proven to be very useful, especially in a environment like this. This scene shows bullets and money, the combination of these two objects influence the sense of negativety, as bullets can link to death and money can mean greed. The message is not meant to be clear, it is a subtle hint that can possibly direct the viewer's perception of the narrative or an insight of the possible events that have taken place (Lerena, 2013).

(Figure VIII) *A rendered shot with subtle metaphors hidden within the scene.*

Referring back to the setting being a "simulated world," there are also symbolic elements hidden in plain sight, implying this concept. *Figure IX* shows two close-ups of objects in *Figure VIII*, a bullet and picture frame. Both these objects have a binary code written on them, indicating hints towards this simulated world. The picture frame has the code *01000001 01001001* which converts to *AI* in text, referring to artificial intelligence. The practitioner has hidden a few elements, of such, throughout the scenes. The

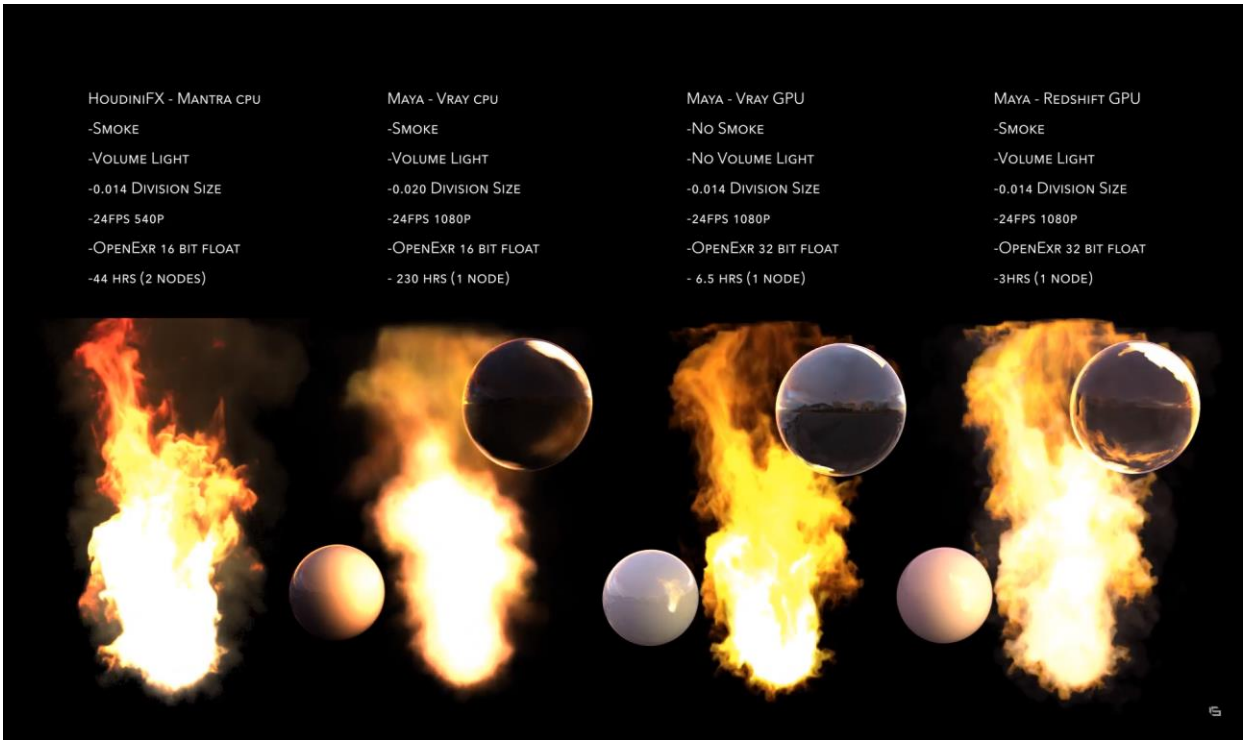
purpose of these visual symbols is not particularly for the audience, it is actually a hidden feature for the character to discover as it links to the storyline. It is a method of supporting the narrative, a sense of foreshadowing. Not intended to, but if these symbols were to be discovered by viewers, they would provide information on future events, or past events.

(Figure IX) *Binary codes hidden in the scene.*

As seen in the *Figure IX,* the bullet has been enhanced by color and contrast to clearly see the binary code. They are not visibly clear, but each bullet represents a specific letter. As you can see in *Figure VIII,* there are ten bullets in the foreground, ignoring the one in the far back, with their base facing towards the camera, converting and reassembling these codes would spell *SIMULATION.* These codes are very hard to read in the initial contrast seen in *Figure VIII*. Changing the color, contrast and lighting can enhance the visibility of these codes; unfortunately, this is not an option. Since, the perception of color can enhance a certain emotion or attention towards an object or character (Lerena, 2013). Enhancing the bullet's features and color could enable unwanted attention; also, adjusting the temperature and contrast of the scene can change the mood of the scene. The visibility issue may be contradicting the previous statement made, "not intended to be seen by the viewer". To be clear, the idea is for these symbolic messages to be available for discovery, how ever subtle it may be, rather than it being completely unreadable. However, the decision was made for the object to remain untouched and to leave the codes at their current states.

Additional Technical Knowledge

A test was conducted, to evaluate the rendering process and conclude on which rendering engine is most efficient for this particular study, whilst maintaining high quality, in a sense of picture quality and realism. *Figure X* shows this experiment was conducted using four types of rendering engines. This includes Mantra CPU (Houdini), Vray CPU (Maya), Vray GPU (Maya) and Redshift GPU (Maya).



(Figure X) *Testing rendering engines.*

Based on the results, it seems that the first and last flames showed promising results. The issue with Vray CPU (Maya) is that the rendering process was taking so long that it had to be lowered in quality, this flame was rendered using 0.02 division size compared to the others being 0.014. This still resulted in a blurry flame that took 230 hours to render, so this was considered the most unreliable rendering engine for this study. Secondly, Vray GPU (Maya) rendered an adequate flame, with no loss in quality and little time taken. Except, this rendering engine seemed to have trouble rendering smoke and volume light, as it is not present within the flame.

The Redshift GPU (Maya) rendering engine had successfully rendered an aesthetically pleasing flame and showed no signs of failure. Rendering time was recorded to be around 3 hours, very little compared to the others. Mantra CPU (Houdini) competes well with Redshift and had rendered a great looking flame. Unfortunately, the rendering process took 44 hours, with the help of a second computer.

It is clear that Redshift has proven to be the reliable rendering engine for this study, and this was true at the time being. As this was a rendering engine used in Maya, the software's performance had drastically dropped, making it hard to work with. In addition, the simulations that were rendered in Maya were exported from Houdini and re-imported through a Houdini Engine application available for Maya. Ultimately, the final decision was to utilize Mantra as it seemed to show promising results and proved to be the most reliable.

Conclusion

Summary

This research has analysed the factors of the hyperreal movement and the impressions it can leave upon expressive storytelling, through the concept of non-anthropomorphism. The aspects of hyperrealism this research has explored are perceptual realism, visual metaphors and photorealistic imagery. While these aspects are important in regards to digital storytelling, the developed artefact(s), that excludes anthropomorphism, shows that without the integration of multiple storytelling elements, a narrative and film can seem to be simple and confusing. These aspects immensely contribute towards digital storytelling and influence the character's storyline; they allow the viewer to indirectly sense the mood of the scene, directing the viewer's thought process towards a certain idea.

The study and the implication made by (Nicholls, 2017; Lerena, 2013; Wilson& Soranzo, 2015) reveals that the human mind has the ability to understand the smallest of perceptual cues, though the perception may not be clear, it is considered to be in the form of a sensory and emotional feeling. This type of sensory data that triggers the viewer's perception is usually encompassed within the artefacts or objects that construct the scene, it can be the presence of an object, the placement of an artefact, a particular color present in a specific scene, etc. They are subtle perceptual elements that trigger a sense,

indirectly direct the viewer's thought process, and can prove to be very effective. The concept of realistic imagery has enhanced these perceptual cues to be indiscernible, allowing for seamless integration. The technology of this time has introduced immersion to an interactive level. VR is an innovation commonly used for video games and provides this sense of interactivity, whether it be a video game or not. Through this study, the discovery of analogical juxtaposition has proven to be another form of interactivity, almost like the concept of a video game. The artefact created in this study includes the use of visual metaphors with implications towards the underlying storyline, hence the simulated world. The metaphor represented in the scene is a binary code implying this idea, also in addition to this metaphor the binary code itself can be decoded to, in a sense, "leak" information, regarding the narrative. This form of interactivity requires the viewer to analyse the scene, with a little extra effort. This immersive concept allows the viewer to feel involved, enabling the viewer to decode storylines that may link back to the original narrative. Through this research, it is clear that a narrative is genuinely a complex network of mental space, which eventually merge to reach a final mental representation.

The practice-based approach has evidently contributed to the development of an aesthetically accurate flame and a progressive advancement of technical knowledge; however, the exclusion of non-anthropomorphic attributes, whilst maintaining the expressive notion, has proven to have its limitations. It is quite difficult to express a sense of mood through the flame alone. The absense of limbs, facial expressions and other human characteristics left the character to be expressed through only a few forms of a flame. The character would be able change between a flame resembling a candle and a vicious flame emitting ember and smoke. To show an emotion or reaction, the flame would show a subtle change in phase. For example, a slightly irritated character would release ember and a character showing anger would release ember and smoke. The difficulties of this character was the visibility of the tansitional phase. Within the Houdini application, the changes were applied through the parameters, except the flames did not seem to effectively reflect the transitions. This did leave the flame to depend on the context of the environment, regarding the subtle elements of perceptual cues and visual metaphors. Overall, it is evident that perceptional cues and visual metaphors, in conjunction to realistic imagery can immensly contribute to the narrative. The presence and the combination of these elements provide a sense of direction and context for the flame, it is then left for the audience to decode in respect to their own interpretation.

Technical Limitations

The completed artefact(s) generated through this research was intended to playback at 48fps rather than the standard 24fps. The reason behind this intention is due to the fact it would truly support the concept of a simulated world. As researched, the effect of 48fps eliminates motion blurring, therefore creating smooth motion. (Michelle, Davis, Hight, & Hardy, 2017). It is also mentioned that HFR has proven to be unconvincing and unnatural, proving the statement of perfection being derived through imperfections (Sparnaay, 2002). The unnatural motion of the character or camera would influence the sense of artificial world, hence the concept of the world being a simulation.

The limitations, due to render times and time constraints, 48fps had to be excluded from the final artefact. Rendering 48fps would mean the render times would take twice as long compared to the standard frame rate, whilst consisting of little to no smoke, since smoke has proven to add a lot of time to the rendering process. In regards to the scene, many of the photorealistic textures and displacements had drastically increased the render times. It would have been unwise to continue the creation of this artefact at a frame rate of 48fps.

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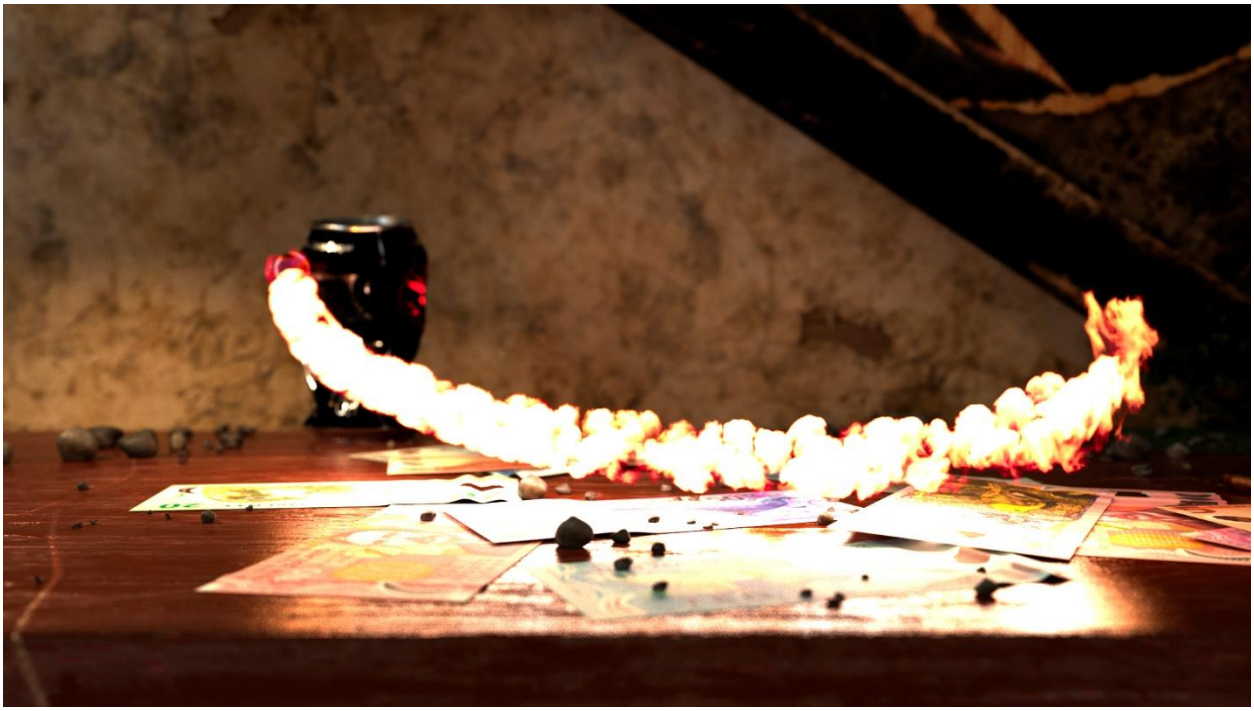
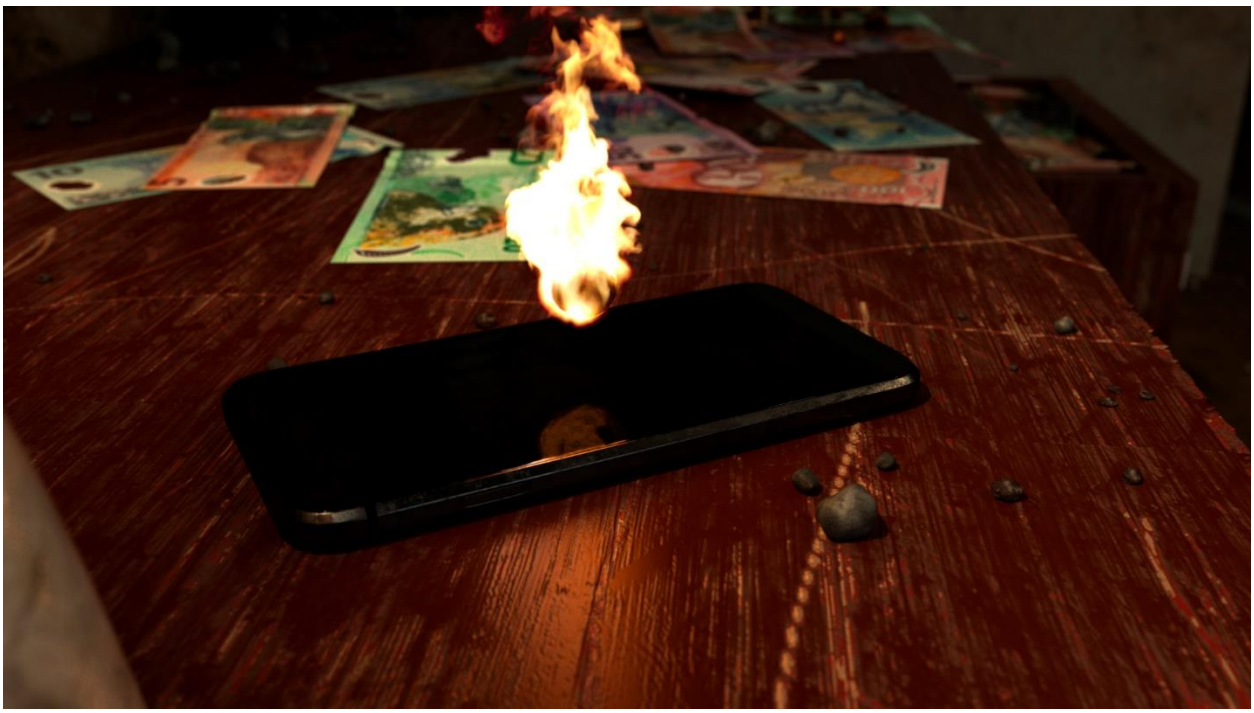
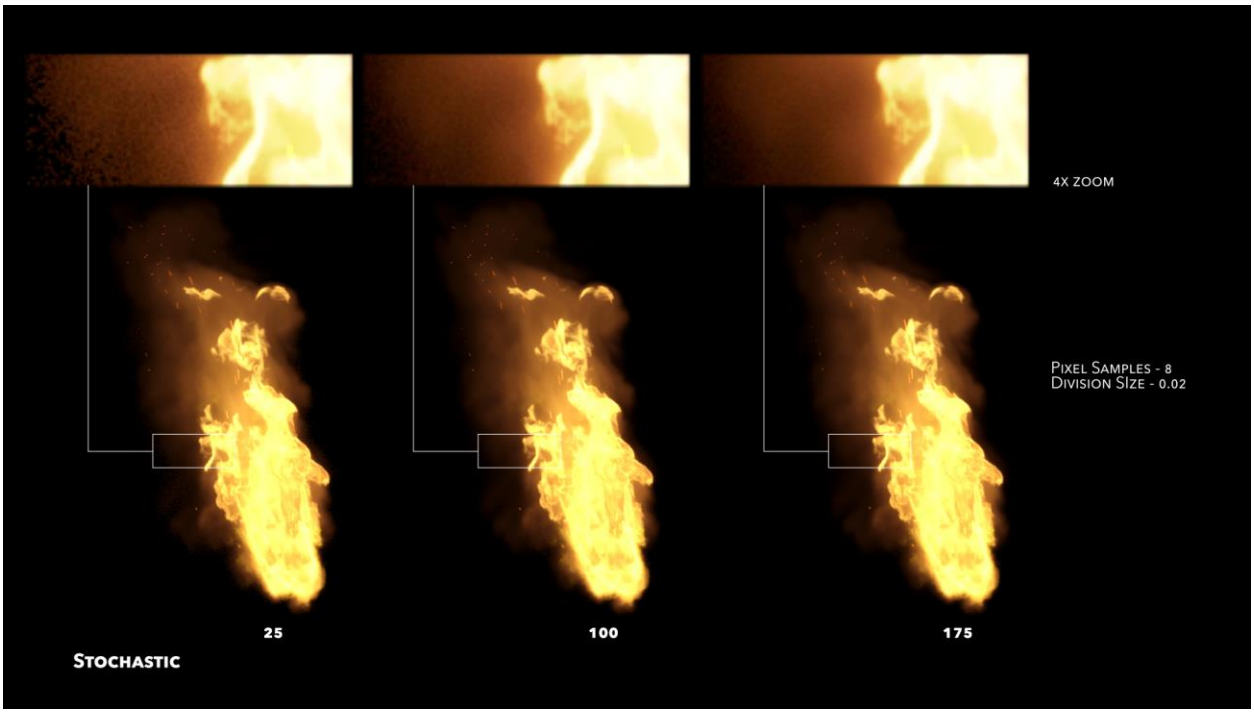
Appendix

Artefact

The creative artefact was presented as a short rendered full HD sequence with a length of 1m 23s on a screen for examination. In addition, there was a breakdown of the key elements, such as ‘Flame Trials’ with a length of 2m 20s. The examiners were given a brief verbal introduction about the creative artefact.



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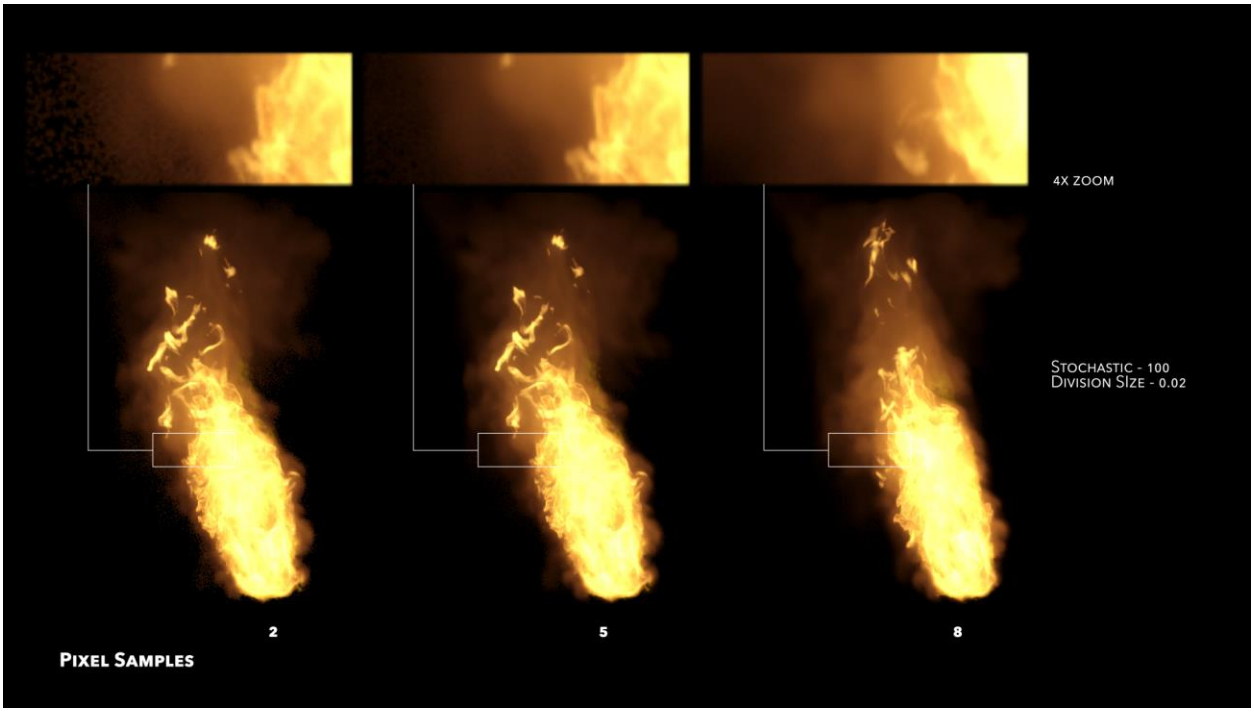
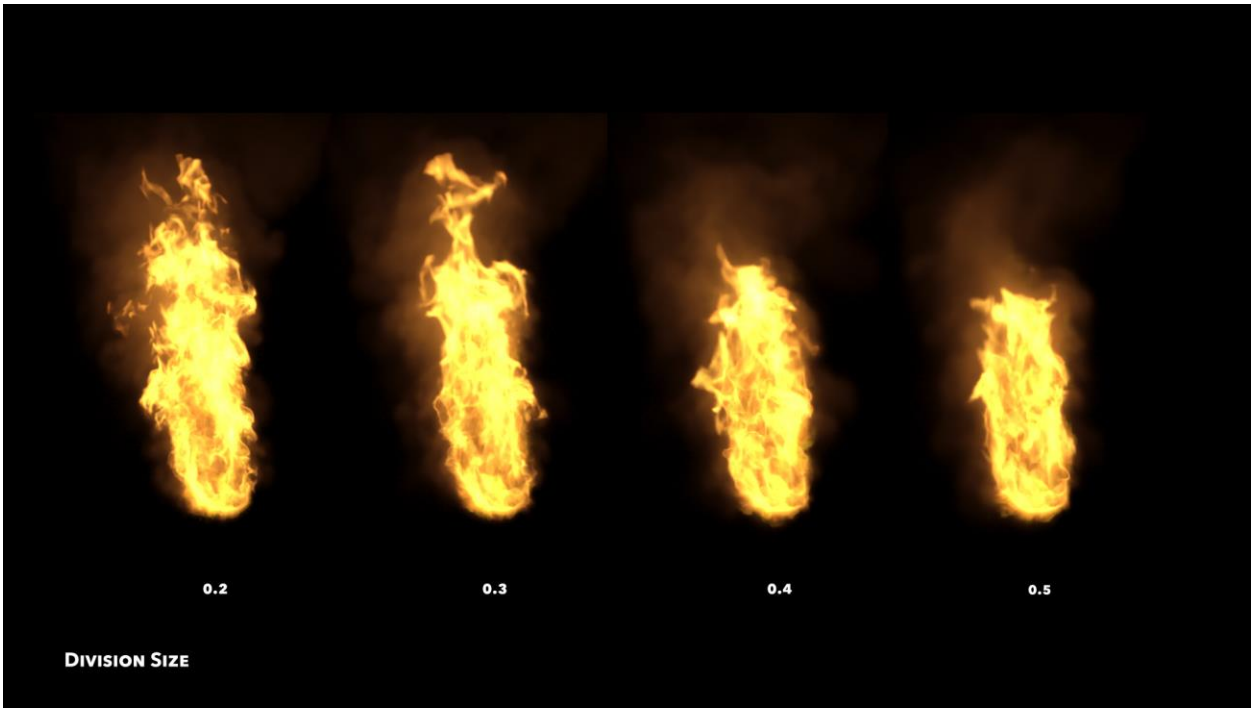
PIXEL SAMPLES - 8
DIVISION SIZE - 0.02
25
100
175
STOCHASTIC


4X ZOOM
STOCHASTIC - 100
DIVISION SIZE - 0.02
2
5
8
PIXEL SAMPLES


0.1
0.5
1.0
1.5
TURBULENCE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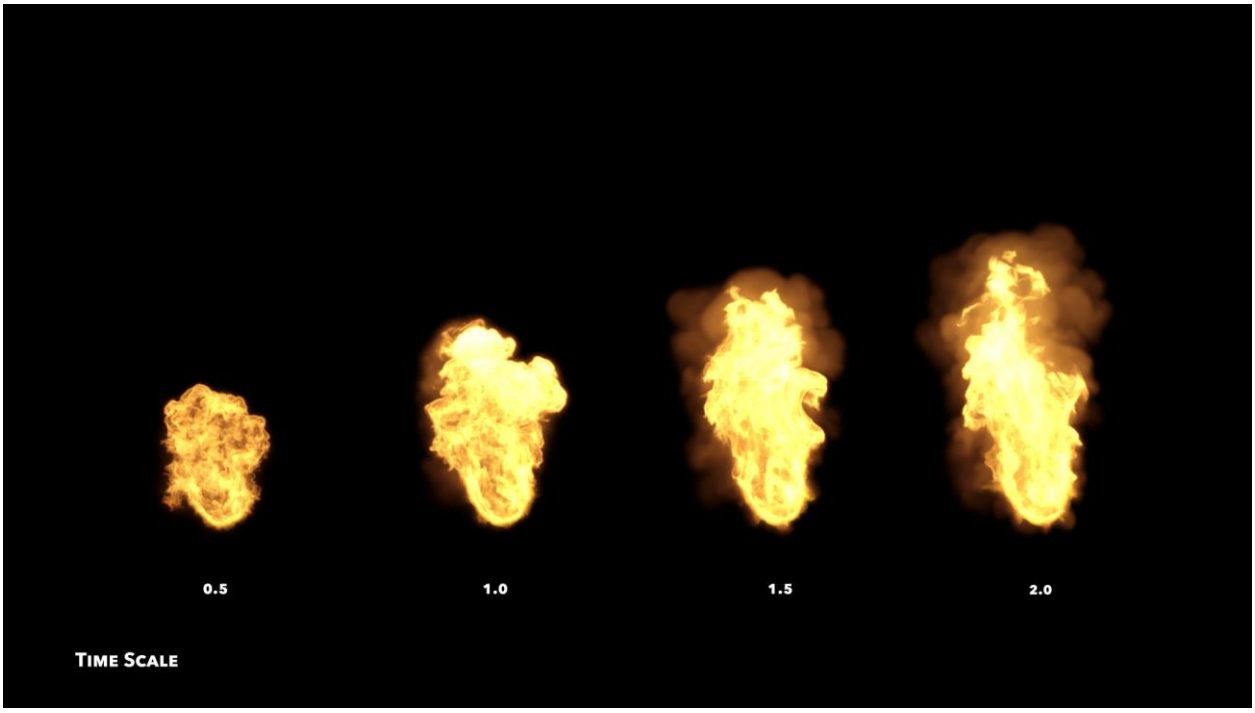
0.3
0.4
0.5
DIVISION SIZE


0.1
0.5
1.0
1.5
SHREDDING


0.5
1.0
1.5
2.0
TIME SCALE