Development of film production software for a clinical application of advanced MRI technologies

Pedro Santos

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Universidade do Minho
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Guimarães, de setembro de 2022

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CHAVE MÓVEL

(Pedro Afonso Rodrigues Santos)

Agradecimentos

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Obrigado a todos, e quando fecha-se uma porta, abre-se uma janela...

DECLARAÇÃO DE INTEGRIDADE

Declaro ter atuado com integridade na elaboração do presente trabalho académico e confirmo que não recorri à prática de plágio nem a qualquer forma de utilização indevida ou falsificação de informações ou resultados em nenhuma das etapas conducente à sua elaboração.

Mais declaro que conheço e que respeitei o Código de Conduta Ética da Universidade do Minho.

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“It does not matter how slowly you go,

so long as you do not stop”

Confucius

Resumo

A Imagem de ressonância magnética **(IRM)** é uma técnica que visualiza as estruturas internas do corpo através de campos magnéticos poderosos e ondas de rádio, e ao contrário dos *Raios-X*, um exame de ressonância magnética não usa radiação. Normalmente esta técnica é usada para detecção de doenças, monitoramento de tratamento e diagnóstico. Tem um grande impacto na **Neurociência** desde que começou a ser desenvolvida nos anos 70 e 80, especialmente porque a Ressonância Magnética funcional **(IRMf)** e a Ressonância Magnética de difusão **(IRMd)** aumentam a eficiência da ressonância magnética, embora as técnicas de IRMf e IRMd tenham tido muito pouco impacto nas aplicações clínicas.

Os estudos e resultados recentes da IRMf têm sido progressivamente aprovados por médicos e pesquisadores, pois são capazes de fornecer informações únicas sobre as funções cerebrais, no entanto, quando se trata de melhorar o atendimento clínico, os resultados têm sido muito limitados e a utilização de estímulos audiovisuais avançados de IRMf foram quase nulos. Uma das abordagens recentes que é adequada para criar um estímulo audiovisual avançado de IRMf, e é útil em aplicações clínicas (por exemplo, *Transtorno de Déficit de Atenção e Hiperatividade* (TDAH)) é a IRMf cinematográfica. Um dos problemas principais das técnicas cinematográficas de IRMf é identificar uma determinada patologia que varia muito entre todos os filmes e patologias, ou seja, encontrar e fazer um filme adequado para cada patologia é muito caro e demora muito tempo.

Neste projeto, iremos explicar o desenvolvimento de programas de software que estão interligados a um cérebro-máquina para que os scripts possam ser transformados em animação por computador.

Palavras-chave: Produção de filme, Edição de guião, Reconhecimento de palavras, Realidade virtual, Multimedia.

Abstract

Magnetic Resonance Imaging **(MRI)** is a technique that visualizes internal structures of the body through powerful magnetic fields and radio waves, and unlike *X-Rays*, an MRI exam doesn't use radiation. Normally this technique is used for disease detection, treatment monitoring and diagnosis. It has a great impact on **Neuroscience** since it started to develop in the 1970s and 1980s, especially since functional Magnetic Resonance Imaging **(fMRI)** and diffusion Magnetic Resonance Imaging **(dMRI)** increase the efficiency of MRI, even though, fMRI and dMRI techniques have had very little impact on clinical applications.

The recent studies and results of fMRI have been progressively approved by physicians and researchers as they are able to provide unique insights into brain functions, however when it comes to improve clinical care, the results have been very limited and the usage of advanced fMRI audio-visual stimuli have been almost null. One of the recent approaches that is suitable to create an advanced audiovisual fMRI stimulus and it's usefull on clinical applications (e.g. **Attention Deficit Hyperactivity Disorder** (ADHD)) is the **cinematic fMRI**. One of the main issues of the cinematic fMRI techniques is to identify how a given pathology varies greatly across all films and pathologies, so in other words, to find and make an appropriate film for each pathology is very expensive and time consuming.

In this project, we will explain the development of software programs that are interconnected to a brain-machine so that scripts can be publicly transformed into computer animation. These programs can be used to detect a pathology that causes a change in film interfaces and other applications.

Keywords: Movie making, Screenplay editing, Word recognition, Virtual Reality, Multimedia.

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1 Introduction

Key points:

- To understand the importance of fMRI and its clinical applications, and how they can be related to the film industry;
- To show the benefits of Video Games and its similarities between this and to film industry;
- To study the topic of Artificial Intelligence and its implications.

1.1 Motivation for this project

For the last three decades, **Magnetic Resonance Imaging** (MRI) has had a significant influence in Neuroscience, especially, with the use of **functional Magnetic Resonance Imaging** (fMRI) and **diffusion Magnetic Resonance Imaging** (dMRI). However, these two techniques have had little impact in clinical applications. With the help of recent **Artificial Intelligence** (AI) approaches, the movie fMRI is used to obtain brain imaging-base markers of psychiatric illness, and the dMRI technique is used to obtain a novel coordinate system of the human cortex inspired by new models of cordico-cortical wiring defined using postmortem anatomical studies.

In some recent developments (Paquola et al., 2020) of integrating dMRI with local MRI assessment of myelin concentration, and the use of curved spaced topologies, have allowed for a strong correlation with what was gathered from humans in a **resting state** (rs), where the data was either rs-fMRI or electroencephalography (EEG). Regarding to the rs-fMRI, the data obtained two axes: an anterior-posterior axis and a sensorial-multimodal axis; while the EEG data also obtained two axes: an anterior-posterior axis and a limbic-prefrontal axis (Paquola et al., 2020).

The capacity for fMRI to improve clinical care has been very limited, however, a recent approach (Eickhoff et al., 2020) suggested movie fMRI as a form of creating an advanced audiovisual stimuli fMRI that is useful for clinical care, for instance, the case of **Attention Deficit Hyperactivity Disorder** (ADHD) (Salmi et al., 2020). However, one of the main problems of the movie fMRI approach is that the usefulness of movies for identifying a certain pathology differs a lot across the movies and pathologies, therefore, a person must find and/or make the appropriate movie for each pathology, which is an issue because the development of a movie can be very expensive (Eickhoff et al., 2020) and finding the appropriate movie is very time-consuming.

The use of movies as stimuli in fMRI research has increased immensely since 2004 (Hasson et al., 2004). For psychiatric imaging in particular, this technique provides multiple advantages (Eickhoff et al., 2020), such as:

1. The ability to drive higher-order neural processes;
2. Enhanced signal properties;
3. Improved data quality and quantity.

Another advantage of using movie fMRI is that it allows the possibility to evoke attentional performance during complex social processing in ADHD, or demonstrate the existence of a distorted sense of reality in psychotic illness (Salmi et al., 2020). For instance, when watching a movie clip of a complex social conversation, no neural differences between ADHD and non-ADHD participants are detected. However, if auditory distractors are added, there will be a difference between ADHD and non-ADHD that is detected (Salmi et al., 2020). Futhermore, if fMRI and EEG are combined (Eickhoff et al., 2020), it's possible to obtain a 3 axes system that is in agreement with the 3 axes of brain anatomy/skeleton anatomy/evolution/Darwin Evolution Stages/Emotional Map/Transcendental Perspective and multiple other features which allowed to define a 3 axes map of mental health (Lori et al., 2019). Thus, the use of movie fMRI+EEG allows for detecting a large array of mental pathologies.

1.2 functional Magnetic Resonance Imaging

1.2.1 What is functional Magnetic Resonance Imaging?

The neurons within the brain changes when a person performs various activities, from a simple labour like picking up a remote to a complex task like understanding sign language. The anatomy of the brain allows to have different patterns when it comes to language, memory, touch, hearing, taste and vision.

The development of **functional Magnetic Resonance Imaging** (fMRI) in the 1990s ((Ogawa et al., 1992), (Kwong et al., 1992), (Bandettini et al., 1992)), is a variation of the **Magnetic Resonance Imaging** (MRI) and a type of non-invasive *brain imaging technology* that can measure brain activity by analysing changes in the blood flow. An fMRI can demonstrate the parts of the brain that are active during a specific task, allowing researchers to use this information to monitor and treat various conditions.

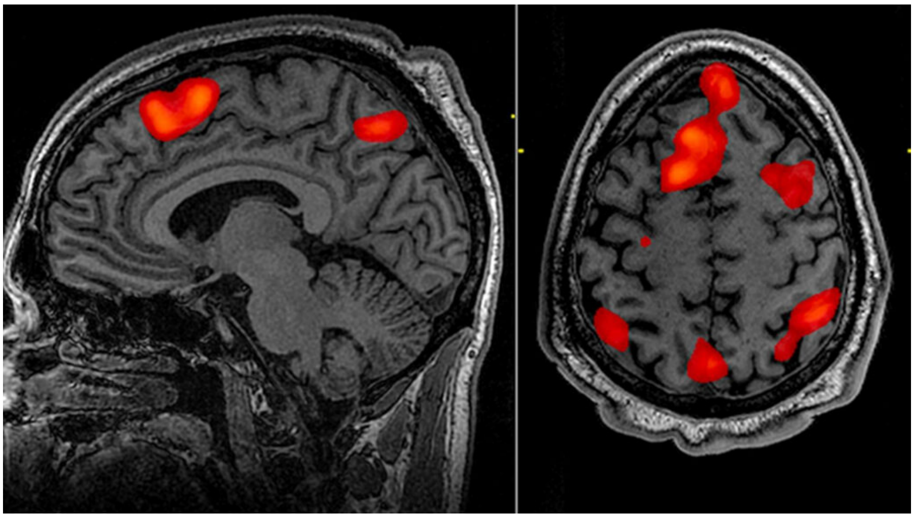


Figure 1: An fMRI image with red areas indicating brain activity.

This technique is mostly performed using the differences in the paramagnetic properties of oxyhemoglobin and deoxyhemoglobin, also known as blood oxygenation level-dependent (BOLD) contrast (Ogawa and Lee, 1990) to generate images of the cerebral activity. The magnitude of the BOLD signal shows the changes of the synaptic input and intracortical processing of a certain volume (the total synaptic activity), it is the output of the neurons in that area. Therefore, it's used that the increase in synaptic activity accompanying brain activity gives origin to a BOLD signal. As local neuronal activity increases, there is a delay that occurs before the regional vasodilation and the increase of the flow. This process is referred as the hemodynamic response function (HRF). An HRF models the usual change in BOLD signal over time after a stimulus. The time-scale of HRF is on the order of seconds, whereas the time-resolution of the electroencephalography (EEG) signal is a lot faster.

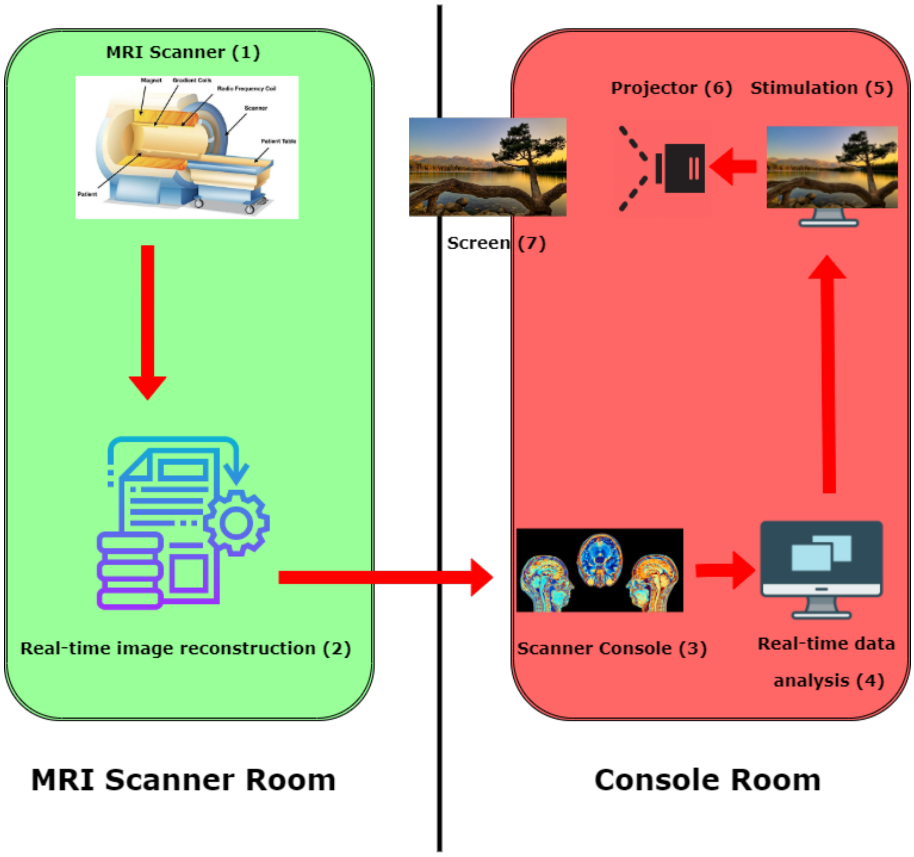


Figure 2: Dataflow during real-time fMRI. Once the functional data is acquired **(1)**, the images are reconstructed **(2)**, they are sent to the scanner console's hard disk **(3)**, the computer analysis the data **(4)** and has access to the reconstructed images and the data being processed. To provide neurofeedback information, the console transfers its output to the stimulation PC. For example, it generates an image of a sunset with a lake for visual neurofeedback information **(5)**, which is displayed via the projector **(6)**, onto the screen **(7)**.

This method has established recent fMRI studies to investigate several neuronal responses to various forms of stimuli and activities during the performance, such as periods of brain activation during a task, or a rest position ((Bandettini et al., 1992), (Blamire et al., 1992), (Vallesi et al., 2015)). They also contributed to this paradigm shift and led to the recognition that the human brain is considered to be a network of functionally connected and constantly interacting areas that require a focus on how to understand the connectivity patterns as well as localized activation (Biswal et al., 1995). As a result, the examination of the resting state fMRI (rs-fMRI) depends on brain activity to show signal fluctuations in the absence of external stimuli or the request of tasks that were appointed ((Damoiseaux et al., 2006), (Fox and Raichle, 2007), (Schölvinck et al., 2010), (Friston et al., 2014)).

1.2.2 Clinical Applications

The fMRI technique has no doubt expanded significantly the areas of neuroscience, such as the study of personality traits, making decisions, understanding a language, visuospatial orientation and memorization.

In the matter of the epilepsy treatment, fMRI always deals the arrangement and execution of surgery, bearing in mind that fMRI-based motor mapping is very useful when lesion borders need to be identified, even with the flexibility in fMRI based motor mapping, it should always make a decision about the resectability of a certain brain region (Roux et al., 2003). One of the goals of Wada testing is to predict the language outcome. Modern research have discovered that fMRI has a bigger association with naming result than Wada testing. It can also used to characterize the basic perimeters of main indigenous language in the area of an arranged operation, in particular, language mapping is important to set a planned surgery. In addition, it can be use in conjunction with EEG (EEG-fMRI), offering alternatives to locate epileptogenic lesions in patients.

fMRI has been a useful tool when dealing with brain tumors, as it can highlight the connection between the tumor and the eloquent functional areas (Hall et al., 2009), to estimate how the brain tumor has affected the cortical areas that involved speech and language ((Atlas et al., 1996), (Signorelli et al., 2001), (Signorelli et al., 2003), (Bizzi et al., 2008)), and althought there's less evidence, it can map cognitive functions (Ota et al., 2009). There are circumstances implying that fMRI is very accurate in anticipating the position of excitable areas in contrast to language areas ((Roux et al., 2003), (Kapsalakis et al., 2012)), while other researchers praise the great harmony between fMRI and intraoperative mapping details (Jimenez De La Pena et al., 2013). Nevertheless, the methods of electrophysiologic and imaging were planned to aid doctors in attaining safety measures, and fMRI is being integrated with several methods such as diffusion tensor imaging to obtain the ideal results.

1.2.3 fMRI and cinema

fMRI research has expanded remarkably with the use of movies as stimuli, since 2004, showing that BOLD-signal time-courses throughout large sections of cortex were integrated in all the patients (Hasson et al., 2004). One interesting subject is that this research showed evidence suggesting that such such conditions could result in unique brain-based findings ((David et al., 2004), (Spiers and Maguire, 2007), (Hasson et al., 2010), (Sonkusare et al., 2019)). When it comes to psychiatric imaging, movie fMRI can provide some advantages:

1. Being capable to drive higher-order neural processes;

2. Improve signal properties;

3. Better quality and quantity of data.

While it's hard to believe that this could evoke attentional performance during the process of attention-deficit hyperactivity disorder (ADHD) ((Rikandi et al., 2017), (Salmi et al., 2020)), it is possible. So movies have the potential to provide to the human brain a way to analyse the whole organ while it works and could be used for comparison across different levels of intensity.

The combination between fMRI and movie-watching could be very helpful for biomarker research, and also confers some advantages in rehabilitation, for example improving the participant's engagement and compliance, and provide an increment of improvement when identifying clinically relevant differences in signal (O'Connor et al., 2017). To some extent, movie fMRI allows researchers to avoid the recurrence of stimuli needed with most conventional tasks, and is able to capture brain dynamics under complex situations, preserving the ability to detect patterns of functional connectivity that are distinct at the individual level. One thing worth mentioning is the amount of data movie fMRI can provide, in this case, movies can serve as a bridge to differentiate human versus nonhuman brain functions.

An advantage for this technique is that movie-watching can increase scanner tolerability, in other words, it can be useful for people that have difficulties in keeping their head still during scanning, those who are anxious, or to stay awake.

The social neuroscience is also interested in cinema, mainly as it replicates life to the same degree ((Tan, 1996), (Mar and Oatley, 2008), (Tikka, 2008), (Grodal, 2009)). Neurocinematics mentions to neuroimaging demonstrations that implement cinematic stimuli to investigate the nature of the human being. So far, these experiments showed how to pay attention to different viewers to ethically control features of the history (facial expressions, body gestures). The unconstrained free-viewing method grants the immersion of the spectator into the theatrical world without interruptions. Although the interactive movie paradigm has brought many ways to produce narrative results, it has a problem: the interruption of the narrative course when spectators make several agreements.

Recently, real-time fMRI (rt-fMRI) (Cox et al., 1995) granted neural activity of several regions in the human brain as useful information, and can surpass a simple direction of region-of-interest established task by authorizing real indicator of practise and network examination. These measures can be achieved by tangential behavioral signals and physiological signals, that allow approaches to expressive situations ((Ravaja, 2004), (Heller et al., 2011)). The distribution of analysis methods in actual time is always growing and therefore, it greatly enhances several chances of reaching a system based on the enactive cinema. There are many additional attributes within the fMRI data that can be accomplished besides the ROIs analyses made in real-time, like the functional and effective connectivity ((Ma et al., 2012), (Lee et al., 2012)), the distribution of patterns ((Hollmann et al., 2011), (LaConte, 2011)), and the conjunction of peripheral study and brain data ((Wilms et al., 2010), (Voyvodic et al., 2011)). This means reports to the system can be more than just simply a linear increase-decrease association of a unique brain region, which allows a more detailed impression of the state-of-mind. Although a single brain region could become part of many contrasting functions, the recognition of a practical network can offer the system new details regarding the growing cognitive procedures, thus allowing a stronger and precise response. The leverages of using response patterns instead of one physiological mean are settled in (Ravaja, 2004), as the precision of the recognition of the psychological, inspirational and analytic cases of a human being can increase by merging the rt-fMRI results with multiple physiological indices.

In these systems, adjustments in the psychophysiological responses of candidates regulate the innovations formed to the display of the story in actual time (Kaipainen et al., 2011). This concept was originally established in the situation of cinema insertion "Obsession", which relied on the tracing of the candidate's physiological replies in actual time, which controlled the algorithm-guided collage of the cinematic language, that is influenced by the candidate's involvement, and so forth (Tikka et al., 2006). This subject can be considered as painting socio-emotional communications through changing circumstantial aspects as a purpose of candidates' experience. This system includes:

1. Real-time acquisition;
2. Investigating the physiological feedback information;
3. "Analysis toolbox" (changes the stimulus course to activate the wanted outcomes).

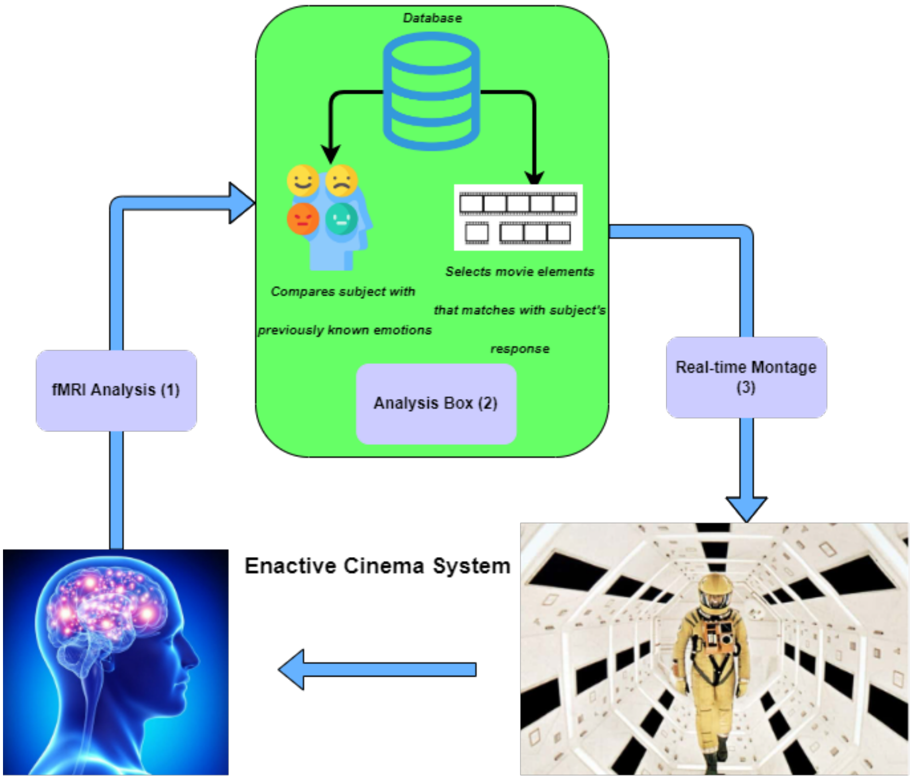


Figure 3: Enactive System Diagram. The subject's physiological feedback are examined in real-time **(1)**, an "analysis toolbox" compares the subject's behavior with with previously known emotions and selects specific movie elements based on the feedback **(2)**, a montage made in real-time is projected to the viewer **(3)**, whose brain responses are scanned, and so on.

1.3 Video Game Industry

1.3.1 Video Game History

Video Games were around in these last few decades, adding amusement for people in all ages, being able to evolve significantly in each generation.

In the early 1950s, computer scientists were using electronic machines to create simple game systems like Tic Tac Toe or Nimrod, in which these systems used electronic light displays to showcase the power of computers at that time (Bateman, 2014). However, in 1962, scientist Steve Russell developed the game SpaceWar! for the PDP-1 mainframe computer at Massachusetts Institute of Technology (MIT). To this day, it is considered to be the first game that could be played on multiple computers, which allowed it to gain popularity (Graetz, 1981).

In the 1970s, the video game industry grew with the development of the first arcade video game and the first home video game console in the United States. In 1972, Atari's Pong was released, and was considered the first successful arcade video game. Later in 1975, Atari released a home version of Pong. Arcade Video Game became popular very quickly in Japan due to the partnerships between the United States and Japan. In the same year, it was released the first arcade to use a microprocessor rather than individual TLL components (Kent, 2001).

However, in 1983, most companies hired novice programmers without experience in the area, which led to questioning the low quality of games like E.T., and cause the infamous Video game crash.

In late 1980s, while the CPU was still an 8-bit system, NEC released its PC engine known as TurboGrafx-16, which used a 16-bit system. In comparison to the 8-bit system, the 16-bit was a big factor in marketing video game consoles for the next decade, with SEGA releasing the Genesis console in Japan in 1988 and in the United States in 1989, and in 1991, Nintendo released the Super Nintendo Entertainment System (SNES). This period was known as the first console war (Greene, 2015).

During the 1990s, the industry started to shift towards 3D games. With the introduction of 3D graphics, Real-time strategy games grew in popularity (Command & Conquer). Later on, online connectivity in computer games became important for First-person shooter (FPS) and Real-time strategy (RTS) games.

Around the mid 2000s, the first smartphones were available to the public, with Apple introducing the iPhone which was technologically more advanced than any smartphone on the market, and included an App store with gaming applications, and Google, which developed the Android system, released its own app store, now known as Google Play (Topolsky, 2012).

With the introduction of flat-screen TVs and monitors which had higher resolution and rates, their hardware introduced the support for the High-Definition Multimedia Interface (HDMI), which allowed resolutions up to 4K.

While Virtual Reality (VR) has been in development in early 1990s, their breakthroughs came in the early 2010s with the Oculus Rift, and later in 2016, Sony released its PlayStation VR. Meanwhile, with Augmented reality (AR), the gaming industry adapted to its technology, in which games take a real-time video game image and renders additional content, allowing players to experience games in a real-world environment (Pokémon Go).

1.3.2 Video Games: the impact of the COVID-19 pandemic

The outbreak of the COVID-19 pandemic, also know as Coronavirus, had a major impact in all aspect of people's lives, virtually speaking, with the lockdowns restrictions affecting the way how we work, socialize, and so on. By being forced to stay home, children had to stay away from schools, and receive education via Internet ((Daniel, 2020), (Guan et al., 2020), (Elsayed, 2021)). What's more is that not only the children, but adults were more exposed to smartphones, computers and game consoles, since they not only served as a way of entertainment, but also a way to escape stress and anxiety. In many ways, social interaction through online interaction has increased since 2020, weather it would be study or work related (Zoom, Microsoft Teams), or in this case, online gaming (Javad, 2020), making it one of the biggest industries to grow tremendously since the beginning of the pandemic.

However there are strong concerns regarding the consequences of these recent measures that are affecting young people's mental health and behaviors ((Anderson and Bushman, 2001), (Anderson et al., 2010), (Engelhardt et al., 2011)). By considering that the excessive use of video games could alter their behaviours, some studies suggest that as long as there is moderation, video games can be used as a pedagogical tool, a way for someone to concentrate and to perform multitasking, to reduce stress and to positively affect reaction time.

Recently, video games are increasingly being used in education and mental health. Some schools and universities have adopted video games to help stimulate humans in all of the transversal competencies, for instance, the creativity of some people ((Ashinoff, 2014), (Kenwright, 2017), (Hewett et al., 2020)). Furthermore, in the mental health section, several studies have showed how video games can be use to train cognitive skills ((Green and Bavelier, 2015), (Stanmore et al., 2017), (Bediou et al., 2018)).

Like it was mentioned, video games can be incredibly beneficial to reduce anxiety and stress ((Russoniello et al., 2009), (Pine et al., 2020)) for people, and as tools for training cognitive processes. In fact, one of the motives for people playing video games is the satisfaction and the entertainment it offers. Like any other activity/hobby, playing these games helps stimulating dopamine release, which is a neurotransmitter that is connected to human sensations like, for instance, happiness (Koepp et al., 1998). These types of emotions are considered a growth of someone's inner-self ((Fredrickson and Joiner, 2002), (Cohn et al., 2009), (Greenglass and Fiksenbaum, 2009), (Quoidbach et al., 2010), (Gloria and Steinhardt, 2016)), which can be beneficial as it can give people a stronger sense of themselves and improve their quality of life ((Seligman and Csikszentmihalyi, 2000), (Csikszentmihalyi, 2013), (Rankin et al., 2019)).

1.3.3 Writing a Game Script

The video game industry has incredibly become as big, if not bigger than the film and the television industry. Some film studios even made adaptations of some video games, and Hollywood continues to turn bestselling games into films or TV shows, some projects, of course, being successful while others aren't.

Regarding to their narrative, some people believe that writing a game script is the same as writing a screenplay for a film/TV show, and while they share some similarities, such as requiring a high level of concentration, research, patience and creativity, it's not as simple as people might think. When someone wants to become a scriptwriter, it's recommended that they start with short scripts, as writing longer scripts can be more difficult for beginners, however they can work their way up if they keep practicing. It's advised that writers do some research to understand the content that not only they enjoy, but also the target audience. When writing a script, it's important that people find an interest in a specific video game genre, since writing in a area that doesn't engage their attention would make things more difficult. When it comes to video games, some of the genres include FPS (First-person shooter), adventure, RPG (Role-playing game), fighting games, racing, sports and so on.

For instance, when writing an adventure game, scriptwriters need to understand how the story unfolds throughout the game, as well as the characters, their motivations and how they impact the story. Each of the characters that are created need to play a role for the development of the story, as well as finding ways by which players can relate to these characters. It's also important to acknowledge how to outline the major storylines for each script. For instance, there could be a game that requires the player to make multiple decisions, which could lead to different endings of the game, writing for each scenario depending on the choices that were made. This is where their creativity and the ability to arrange content comes to play. By understanding the importance of the outlines before writing a script, it will save more time and could help the writer to fill in the blanks. By writing scripts that requires a great amount of creativity and dedication, they are guaranteed of becoming successful.

When it comes to the major differences between screenwriting and game writing:

- On the big screen, people simply sit back and watch the events being played out; while in video games, players not only watch but also participate in the events;
- In most films and TV shows, there are defined story arcs that include a set up, a midway point, the climax, and a resolution. However there are some games where players can make different choices, which could lead to different outcomes, making the story more loose;
- The average run-time for most films are at least an hour and a half, while episodic TV shows are between ten to thirty minutes. Meanwhile, when coming up with a game script, it's important to make long scenes, since when it comes to the story, most modern games can last 20 + hours, and players should have the option to explore the world and search for information and lore through gameplay and the environment, and potentially additional story that is detached from the main story, giving a more enjoyable gaming experience;
- When the audience is watching a movie, they don't know how the story will play out and what the characters will do next, making them entertained. When playing a game however, instead of just watching, they will control the main character(s), which could influence the story and players will find out new elements in the

story along with the character, making the story more immersive;

- When someone screenwrites a film, action helps moves the story forward, making the scene more appealing, instead of additional/unnecessary dialogue and inner-monologue. In video games, the player is who implements the action and makes decisions, and the game can have voice-over narration to help players to understand the current scene;
- When it comes to the First Person and the Third Person experience, both industries make use of the latter, while the former is mostly used in video games (with the exception of found-footage films). In regards to each each experience, it all comes down to the developers. First Person makes the game more immersive and gives players the feeling that they're inside the game, while Third Person could make the story easier to follow, since players will get to know the character they're controlling.

1.3.4 The use of Video Games in Clinical Applications

When it comes to the research related to video games and people's health conditions, most of them only focus on the negative aspects. Like it was previously mentioned, some video games can expose violence which could lead to aggressive behaviors, aggressive cognitions, and decrease pro-social behaviour ((Anderson and Bushman, 2001), (Thompson and Haninger, 2001), (Haninger and Thompson, 2004)), not only that, but some research indicate that video game violence may increase aggression more than movie violence (Polman et al., 2008). They also have been associated with the increase of obesity (Lanningham-Foster et al., 2006), poor school performance (Gentile et al., 2004), physical injuries (Zapata et al., 2006), motion sickness (Stoffregen et al., 2008), and seizures (Kasteleijn-Nolst Trenite et al., 2002). However, many reports have proven that video games can have positive effects for players (Griffiths, 2002). Playing video games can improve health (Warburton et al., 2007), learning (Annetta et al., 2018), and increase someone skills to solve problems (Chen, 2019), such as puzzle games.

Several studies point the use of addictive video games to be related to certain personality traits such as anxiety, depression (Wang et al., 2018), aggression (Mehroof and Griffiths, 2010), low self-esteem (Ko et al., 2005) and low self-efficacy (Jeong and Kim, 2011), which could lead to stress (Milani et al., 2018), loneliness (Lemmens et al., 2011), and the decrease of educational attainment ((Chiu et al., 2004), (Gentile, 2009)). In fact, there seems to be some research that indicates that this problem is most likely to be found among younger people and males ((Greenberg et al., 2010), (Rehbein et al., 2016), (Estévez et al., 2017)).

While video games can be applied to deflect chronic pain from people ((Das et al., 2005), (Gold et al., 2006)), they also serve as useful tools for health education (Griffiths, 2005), by giving knowledge of diabetes ((Brown et al., 1997), (Kumar et al., 2004)) and self-management of asthma ((Rubin et al., 1986), (Bartholomew et al., 2000), (Yawn et al., 2000)), as well as in other health-related areas, such as improving self-esteem (Baccus et al., 2004), spirometric calculation (Vilozni et al., 2001), psychotherapeutic treatment (Wilkinson et al., 2008), and enhancement of cognitive and physical skills, for instance training surgeons ((Rosenberg et al., 2005), (Rosser et al., 2007)).

Depending on the video game, they can cause a positive and a negative effect. Regarding to the positive side, video games can "train" the player to improve their skills, making them more disciplined through the session, even though some people don't seem to enjoy video games the same way. These types of training can cause some changes on neurological level on how players recognize something, which could increase their cognitive skills. Time management is another skill in which some players are strict on timing events (Anand, 2007), where they have to perform a certain action or they might lose the game. Decision making is where games measure players confidence to solve problems (Morewedge, 2015), and how they might affect the game onwards. Some studies indicate to have positive effects, where people make decisions more confidently. When it comes to the negative side, some researchers have checked that this can create bad habits, showing the connection between the bad behaviour and the violence present in video games, however it's not that easy to show the cause of it, since some players with bad habits can play these games to let out their anger. Another negative effect is by playing a video game more frequently in a longer time frame can affect their performance on a daily basis. Finally, some people tend to lose time playing video games, instead of using that time elsewhere.

1.4 Artificial Intelligence

1.4.1 Artificial Intelligence: Introduction

Artificial Intelligence (AI) is the intelligence displayed by a machine and is considered as high-tech technology that increasingly expands the development and the rearrangement in the fields of business, government and science.

In 1956, AI founder John McCarthy established the term on a conference at Dartmouth College, and years later, McCarthy described it as the science behind the creation of intelligent machines and computer programs ((McCarthy et al., 1995), (McCarthy, 2007)). The idea that machines can recognize, study, behave and inform in such complex environments, similar to what the human species can do or even greater, is supported by many scientists (Nilsson, 1998), some even discuss that AI is considered a division of computer science that aims on making systems that carry out chores that usually require human intelligence ((Russell and Bohannon, 2015), (Chartrand et al., 2017)), while alternatively some suggest it being the foundation of devices capable of acting human-like by simulating a person's consciousness and the way it thinks (Jakhar and Kaur, 2020), while others describe it as a series of applications that enable machines and/or computers the capability to imitate the brain's cognitive functions (Tran et al., 2019). However, the meaning of AI differs in specific algorithmic approaches, such as machine learning, neural networks and deep learning ((Morabit et al., 2019), (WIPO, 2019)).

Regarding to the recent years of AI applications to reshape the economy and employment like computer vision, monitorization, prediction and facial recognition ((West and Allen, 2018), (Dang, 2019)), some articles point that AI could release humans from repetitive and complex tasks. However, there are concerns that the implementation of AI could increase the unemployment rate, as well as for potential threats to security, and privacy (Morgan et al., 2020). While some countries seek to use AI to promote produts and even to start-up businesses like Microsoft, Facebook and Amazon, the United States for example, implement it for national security to prevent cyber attacks (Cath et al., 2018), while in China, AI is used for surveillance ((Feldstein, 2019), (Roberts et al., 2020)).

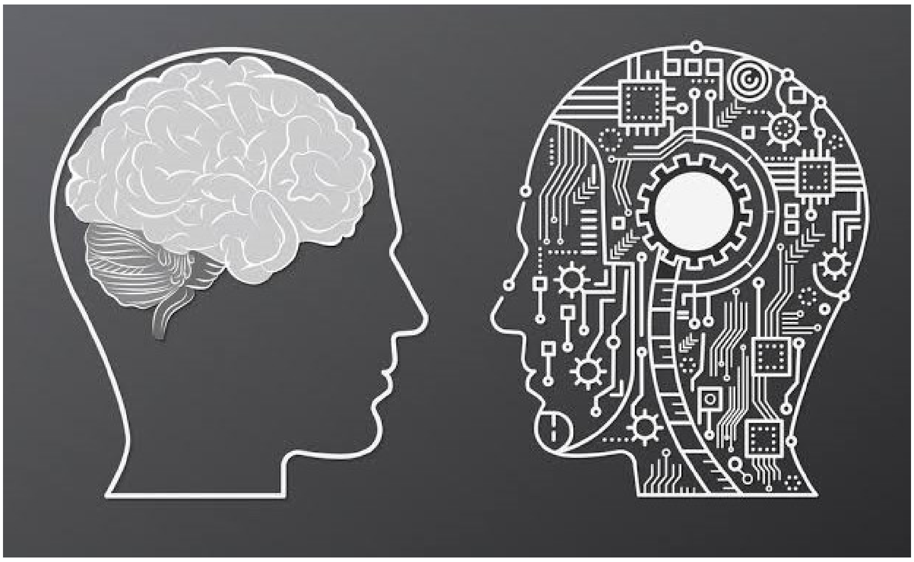


Figure 4: The Human Brain and AI.

In late 2017, *Google DeepMind* developed an AI program named **AlphaZero** which is considered one of the most powerful chess game in the world ((Klein, 2017), (Pete, 2019)). Unlike most programs that were based on experience and strategies from human players, *AlphaZero* didn't have any plays or strategies pre-programmed, rather the developers gave the instructions and rules so that it could create a strategy that maximizes the win-to-loss ratio. Its tactics were unorthodox, but original, to a point the human player couldn't imagine using those tactics, but acknowledged that it could increase the odds of winning the game. So far no one was able to beat the *AlphaZero* program. By following its logic, like recognizing patterns of plays, evaluating the pieces and choosing a play that could guarantee its victory. The chess grandmaster and world chess champion Garry Kasparov was even impressed of what *AlphaZero* was caplable of (Kasparov et al., 2019).

In 2020, *OpenAI* showed a model named **Generative Pre-Trained Transformer (GPT-3** that, when solicited, can generate human type texts. Simply by asking a question, it can give several answers or by giving a sentence it can complete it, or being given some dialogue lines, it can write a potential conversation. Unlike *AlphaZero* that only addresses a specific task, models like *GPT-3* can generate answers for miscellaneous requests. However this tool can be quite difficult to evaluate, since some results look intrinsically human, while sometimes they are just mere repetitions or mechanical combinations of human sentences.

1.4.2 Artificial General Intelligence

Sci-fi films that describe highly intelligent computers and robots usually assume they can understand or can match the human intelligence. Some programmers are even trying to expand the borders of machine learning with the objective of creating a Artificial General Intelligence (AGI). Like AI, AGI it is generally understood to refer to a AI that is capable to perform any intellectual human task, in contrast of the "weak" AI that only performs specific tasks. Despite just being a concept, AGI is referred to have several key features (Goertzel, 2014), such as matching or surpassing human performance across the variety of complex tasks, being capable of handling problems quite different from their creators and to transfer the information that they've gathered.

Even more than the current AI, the machine learning is very important to AGI, although, like a normal human has trouble in understanding something, there are limitations when it comes to a discrete number of domains. One way to develop AGI would be with traditional and specific AI training in various domains, so that they could combine different specialities into a single unit, thus being more "complete" and capable of performing a grand number of tasks, while being less inconsistent and reducing the numbers of errors it can encounter.

However. even if it was possible to currently develop a sophisticated AGI, would it be capable to act like a regular human being? Some scientists and philosophers disagree with this theory. Not only that, but this could create serious issues for even the most experienced funded researchers, as its development would require large-scale computing, around billions of dollars, meaning that only a few number of AGI would be created and few would have the means to create them. Though, either with AI or AGI, the human researchers will still have a bigger role on its creation and operation.

A true AGI should be capable of performing human-level activities and skills that no regular machine can achieve, and while some AI can perform such tremendous and complex activities, they aren't on the same level that would categorize them as human or general intelligence. There are several characteristics that AGI systems should have as we see in all humans beings:

- **Common Sense:** The ability to think and act in a reasonable way and to make good decisions;
- **Transfer Learning:** A method that reuses parts of a previously trained model as the starting point for a model on a new task;
- **Abstract Thinking:** The ability to understand and think about objects, principles, and concepts that are not physically present;
- **Background Knowledge:** Understanding a situation or a problem associated with the words or images encountered in the information that was given;
- **Cause and Effect:** A relationship in which one event (cause) makes another event happen (effect).

Some researchers often refer to it as a ”true AI” or ”strong AI”, as it should theoretically be able to perform any task that a human can exhibit in a range of intelligence in different areas, weather its performance will be as good or better than humans at solving these type of problems. So far there has been great progress towards building this sort of technology, with the development of virtual assistants like *Siri* or *Alexa* where people can interact with a AI in a similar manner as they would with a regular human being. However, while AGI is based on human cognition, this method is based on intellectual potential. In other words, even though this AI can think like a human, for instance telling what the weather will be like, in reality, it can’t reason like one.

In contrast with AGI, Artificial Narrow Intelligence (ANI), sometimes referred as ”weak AI”, is an AI that can surpass a human in a particular task, like search engines and facial recognition. The reason for considering this AI ”weak” is mainly because it cannot think for itself but can simulate the human behavior based on algorithms, rules and parameters. Many existing systems use methods like natural language processing, deep learning and machine learning to self-improve and to solve specific drawbacks.

Narrow AI (ANI)	General AI (AGI)
• This AI is focused on limited/specific tasks.	• This AI performs an extensive number of tasks that require human intelligence.
• Inferior to human intelligence.	• Identical to human intelligence.
• Trained from algorithms, rules and parameters.	• Has the ability to learn, create and apply knowledge.
• Lacks consciousness, self-awareness, and cognitive abilities.	• Has a human-like consciousness, cognitive abilities and expresses emoticons.
• Information is transferred to other areas.	• Leverage knowledge that is transferred to new areas.
• It’s currently available in today’s technology (Virtual assistants, Facial recognition, Drone robots, Recommendation systems).	• Not entirely fulfiled, some scientists and researchers question if it is even possible.

Figure 5: The differences between Artificial Narrow Intelligence (ANI) and Artificial General Intelligence (AGI).

1.4.3 The four types of AI

One of the most recurring themes in AI is the breakthrough of not just the high intelligence of machines but their self-awareness in modern society.

A recent report, written by an assistant professor of integrative biology and computer science named Arend Hintze, explains that AI can be categorized into four types and that it’s important to overcome the boundaries that define these four different types of AI. These are the following categories:

1. **Reactive Machines**

   This type is considered the most basic AI system, having no memory and are task specific. For instance, the Deep Blue is a IBM chess program that can identify the pieces on a chess board, know how each moves and predict the opponents move. However due to its lack of memory, it cannot use past experiences to self improve. Furthermore, Google's *AlphaGo*, although its method is more sophisticated than Deep Blue's by using a a neural network, it can't evaluate all potential moves either. While these methods do improve the ability of AI systems to play these types of games, they have no concept of the wider world. In other words, they don't function beyond the specific tasks that they were given.

2. **Limited Memory**

   Unlike Type 1, Type 2 contains machines that have memory, being possible to access previous experience and use them for later. For instance, self-driving cars can observe other cars' speed and direction.

3. **Theory of Mind**

   Type 3 is a psychology term that, when applied to AI, these systems can understand humans and objects that can have thoughts and emotions, being able to hypothesize human intentions and predict their behavior, allowing them to have social interactions with these systems.

4. **Self-awareness**

   This class focuses on building machines that have a conscious and how they understand it. This of course, is an extension of type 3 (Theory of Mind). Having a conscious means not not only the machines being aware of themselves, but to understand and predict feelings of humans. This type currently doesn't exist yet, and it's probably far from being fully realized.

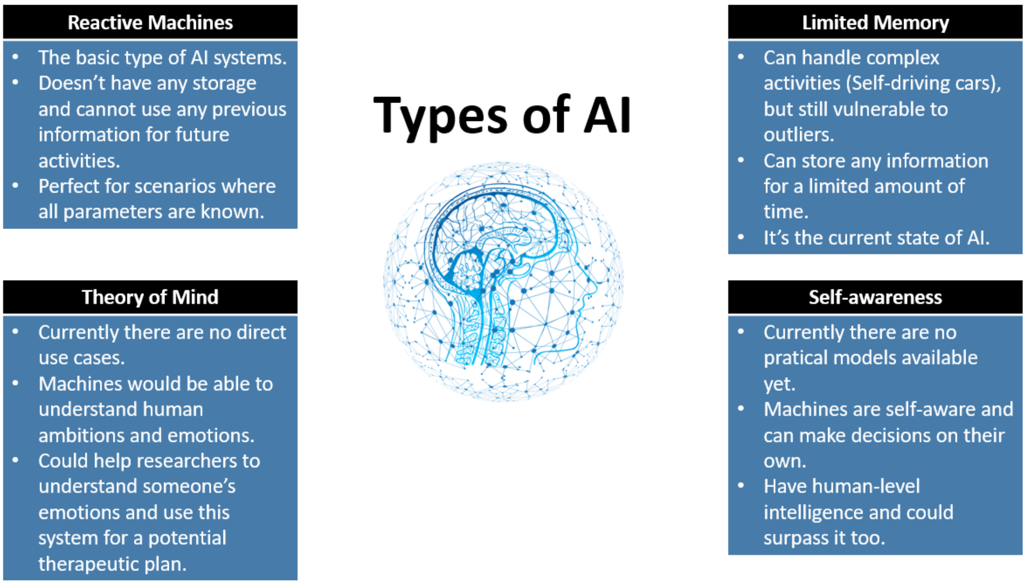


Figure 6: Types of AI: **Type 1** - Reactive Machine, **Type 2** - Limited Memory, **Type 3** - Theory of Mind, **Type 4** - Self-awareness.

1.4.4 AI used in film industry

Like in many professional areas, AI becomes a part of many aspects of the movie industry, such as screenwriting, animating films, cinematography, designing graphics, casting actors, and promoting/distributing movie projects.

- **Screenwriting**: By using AI to generate new scripts could help filmmakers to deal with this assignment more accurately. Since movie script have practically, it would require a huge volume of data, and algorithms like Machine Learning can be useful to analyse it, study it and potentially discover distinctive ideas to create movie scripts. By studying the script, AI programs can also give some suggestions and questioning some decisions made to improve the script.

- **Casting Actors**: AI can automatically cast performers by conducting auditions. They can also do some research in databases that contains information of actors that could fit the criteria (Age, Gender, Nationality). Facial recognition can be used to take the face of an actor and put it on a double to maintain the expressions. They can even de-age actors or create digital characters for Computer-generated imagery (CGI) movies.

- **Movie Editing**: These types of systems are able to recognize specific scenes of the movie, like an high-action scene, and can help editors to make interesting trailers. Like it was mentioned before, facial recognition can be used to determine a certain character and its respective scenes to assist editors in editing full-length feature films.

- **Making Music**: With help form AI-based music composition tools, composers can create new soundtracks for films. With reinforcement learning, AI can analyse data from several music pieces and develop patterns that are fitting to the movie environment and its genre.

- **Movie Promotion**: Several movie studios have use AI for a successful advertising and marketing campaign, by analysing different areas (audience, actors' popularity, locations, genres).
- **Predicting the movie's success**: While some algorithm guesses aren't always accurate, some already attracted a growing interest for several studios. By analysing a movie script, AI can predict the earnings. For instance ScriptBook and the Merlin software utilize machine learning and AI to compare movies to certain audiences.

Figure 7: AI and the evolution of the film industry.

2 Apps in development

Key points:

- To do some research of applications to edit/format screenplays to one person's liking, to apply a video editor where user can input objects and animations.
- To come up with a concept of the integration between the tools developed and the brain-machine interfaces.
- The results obtained indicate if the tools can be used in the film industry and fMRI scans.

In order for these types of movies to be effective, it's important to known how to create appropriate films, but without using many expensive resources. Thus, we need to do some research on how to identify specific mental pathologies and how to create programs that can generate low-quality computer animations and sounds for all the dialogues and background sounds.

One of the objectives for this thesis is to develop computer apps to turn several movie scripts into cheap animated movies, and to follow the cinematographic fMRI approach, so that we can identify different pathologies depending on the films. In this section, we'll focus on each application, the software that are used, and the study of the existing apps and how we can improve these tools, the 3 developed software tools are:

- **OmegaSpec**: A screenplay editing tool;
- **Scriptsheet**: A database tool;
- **MovieBirth**: A movie editing tool/addon made for the Blender software.

OmegaSpec serves to extend the Screenwriting software editing tools so that creative writers and filmmakers can take text from the screenplay that is considered important information and make it indistinguishable. Users can change the color font and replace text in the terminal to fix potential error or making changes in the script.

Scriptsheet serves as a bridge between OmegaSpec and MovieBirth. This tool's main function is to save any information regarding the characters' names, their IDs, the scenes and their time of day, and of course the timestamps that are created with the help from Python's Text to Speech.

MovieBirth serves as a Blender addon which contains 4 tools that will help filmmakers to develop their own low-quality animated films by using all the information gathered from the spreadsheet that was created from Scriptsheet. The Blender software also provides the Modeling workspace to create/import 3D models, the Video Editing for the arrangement of video/audio clips and subtitles, and the Viewport Rendering for the final product.

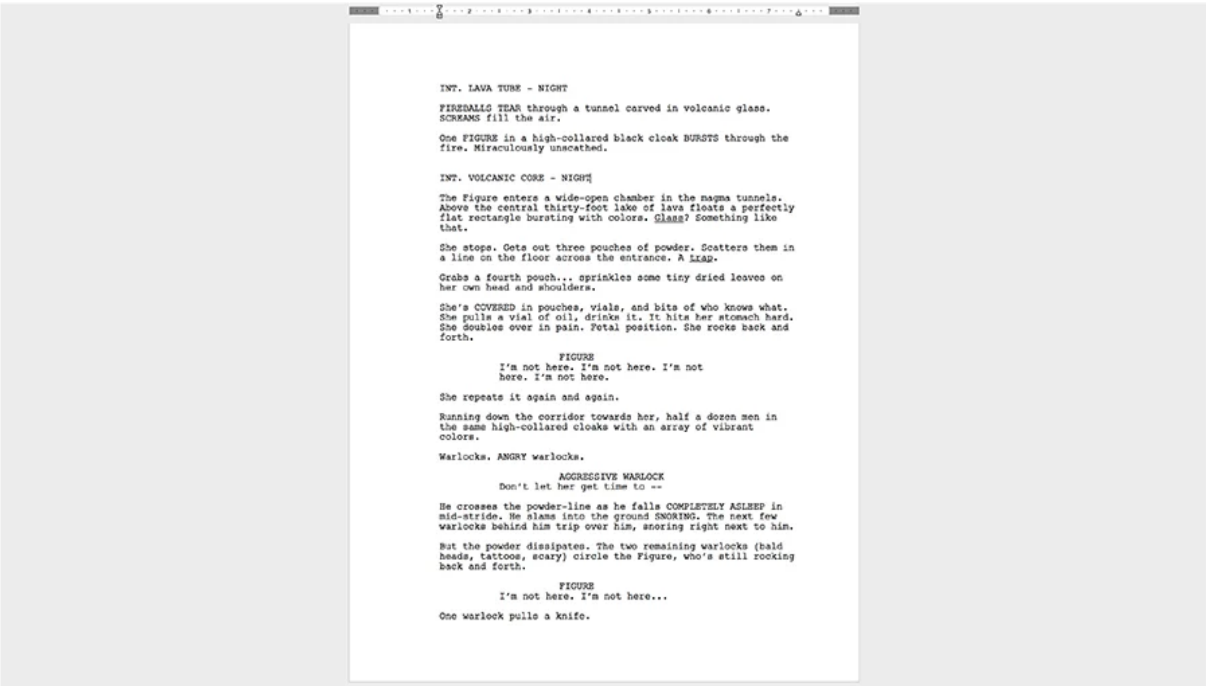
2.1 Support apps

2.1.1 Tools used

For the development of the previously mentioned software programs and languages, these were the tools that were utilized, weather it would be for the screenplay editing, 3D modeling and animation, or movie editing:

- **Final Draft**: A screenwriting software where someone can write and format screenplays. Professional and aspiring screenwriters, producers and directors usually pick this software first. Marc Madnick and Ben Cahan established Final Draft in 1990, with the purpose of creating an app that automatically arranges a screenplay to meet submission standards set by television and film industries. It also brings unique and free educational materials to writers, such as tips and guidelines. In 2013, this project received a Primetime Emmy Engineering Award, and in 2016 it was attained by Cast & Crew Entertainment Services.

Figure 8: Final Draft logo.



INT. LAVA TUBE - NIGHT

FIREBALLS TEAR through a tunnel carved in volcanic glass. SCREAMS fill the air.

One FIGURE in a high-collared black cloak BURSTS through the fire. Miraculously unscathed.

INT. VOLCANIC CORE - NIGHT

The Figure enters a wide-open chamber in the magma tunnels. Above the central thirty-foot lake of lava floats a perfectly flat rectangle bursting with colors. Glass? Something like that.

She stops. Gets out three pouches of powder. Scatters them in a line on the floor across the entrance. A trap.

Grabs a fourth pouch... sprinkles some tiny dried leaves on her own head and shoulders.

She's COVERED in pouches, vials, and bits of who knows what. She pulls a vial of oil, drinks it. It hits her stomach hard. She doubles over in pain. Fetal position. She rocks back and forth.

FIGURE
I'm not here. I'm not here. I'm not here. I'm not here.

She repeats it again and again.

Running down the corridor towards her, half a dozen men in the same high-collared cloaks with an array of vibrant colors.

Warlocks. ANGRY warlocks.

AGGRESSIVE WARLOCK
Don't let her get time to --

He crosses the powder-line as he falls COMPLETELY ASLEEP in mid-stride. He slams into the ground SNORING. The next few warlocks behind him trip over him, snoring right next to him.

But the powder dissipates. The two remaining warlocks (bald heads, tattoos, scary) circle the Figure, who's still rocking back and forth.

FIGURE
I'm not here. I'm not here...

One warlock pulls a knife.

Figure 9: A Final Draft template.

- **Python**: A high-level and popular programming language. Normally it is used in web development (usually on the server-side), Machine Learning apps, and system scripting. It is very favorable for beginners and also experienced programmers. It was created by Guido van Rossum in the late 1980s, and was first released in 1991. When comparing with other programming languages, Python programs are relatively smaller, since programmers can write programs with fewer lines.

Figure 10: Python logo.

```
def pdf2docx():

    filename = input("Enter name of input file: ")
    pdf_file = filename + '.pdf'
    word_file = filename + '.docx'

    parse(pdf_file, word_file, start=0, end=None)
    return filename

def insert_after(paragraph, text=None):

    scriptText = colorText()
    inc = input("Number of Inches: ")
    numinc = float(inc)
    new_p = OxmlElement("w:p")
    paragraph._p.addnext(new_p)
    new_para = Paragraph(new_p, paragraph._parent)
    if text:
        p = new_para.add_run(text)
        p.font.name = 'Courier New'
        p.font.size = Pt(12)
        p.paragraph_format.left_indent = Inches(numinc)
        font = p.font
        font.color.rgb = scriptText

    return new_para
```

Figure 11: A Python coding example, with a PDF to DOCX function and an insert paragraph function.

- **Microsoft Word**: A word processing software developed by Microsoft, and was released in 1983. It is a portion of the Microsoft Office, however it can be purchased as a stand-alone product.

Figure 12: Microsoft Word logo.

- **Microsoft Excel**: A spreadsheet program developed by Microsoft. It is a portion of the Microsoft Office. With this application, data analysts and other users can make information easier to view as data can be added or changed. It also contains a large number of cells that are ordered in rows and columns. Most businesses and companies use Excel for collection of data, data analysis, graphic tools, pivot tables, account management and a macro programming language named Visual Basic for Applications (VBA).

Figure 13: Microsoft Excel logo.

- **Windows Notepad**: A simple text editor that creates and edits plain text documents.
- **Visual Studio Code**: A source-code editor available on Windows, Linux and macOS. It's a free coding editor and uses any programming language, such as C++, Node.js, Python, Java and Javascript. It also features debugging, syntax highlighting and embedded Git.

Figure 14: Visual Studio Code logo.

- **Blender**: A 3D computer graphics software that is available to the public for free, and it's used to create animated films, 3D models, rendering, motion tracking, video editing, and virtual reality. Blender also supports Python scripting to create custom tools and applications, and also allows for blending with external render engines through addons. This application is very useful to users and small studios.

Figure 15: Blender logo.

- **Mixamo**: an online database of characters and animations where anyone can access and can be used in movies and games. Was founded in 2008 and started out as a cloud-based service that would auto rig characters. It was acquired by Adobe in 2015. It is a free tool and users only need sign up for a free account, and supports most of the game engines, such as Unity, Unreal Engine and even Blender.

Figure 16: Mixamo logo.

2.2 OmegaSpec

2.2.1 What is OmegaSpec

While **Final Draft** offers several tools to edit a script, the purpose of developing OmegaSpec is that not only reads the full screenplay, but formats the document by taking different characteristics of a certain character. The current version of this tool is a graphical user interface (GUI), where it displays all sorts of information in a terminal and all the commands are typed on a keyboard at the prompt to start responses from a computer. In Final Draft, while it can export into several document formats like PDF, OmegaSpec only works with word documents, fortunately it includes the option to convert a PDF to **Microsoft Word Document** (DOCX).

On Word, it's important to have the ruler option turned on (with inches), as the program follows certain patterns to find specific data. For most screenplays, the text on the left it's usually related to the information about the environment, the character or a scene; the text on the center refers the character's dialogue; and the text on the right is the transition between scenes or the page number.

The generated script creates different sections while it reads and collects data from the original script:

- **Yellow/Gold**: The action lines that normally refers what is happening in the scene. It can include a name of the character and its biography, background sounds, the world around the characters and their actions;
- **Brown**: The dialogue lines that indicates what each character is saying;
- **Dark Cyan**: Transition between scenes (CUT TO:);

- **Red**: Scene Heading. Indicates where the scene takes place and the time of day. The program includes the number of the scene to help the viewers to differentiate the settings;
- **Blue**: Character names;
- **Green**: A brief description of a character (age, gender, clothing, attitude);
- **Pink**: Background Sounds;
- **Purple**: The Characters. When the program finds the characters in the dialogue lines, it add the number of the scene next to the character;
- **Jade**: Character's ID. After finding the characters, the program also adds an ID to separate each action.

In case the user is not satisfied with the current script, either by a certain character or an action, the user can replace the text by simply writing on the terminal, or differently, when a person is on a fMRI scanner and wants to modify the script through a pathology. The user can utilize the editor to simply replace a sentence, or by adding a new paragraph and choosing a font color.

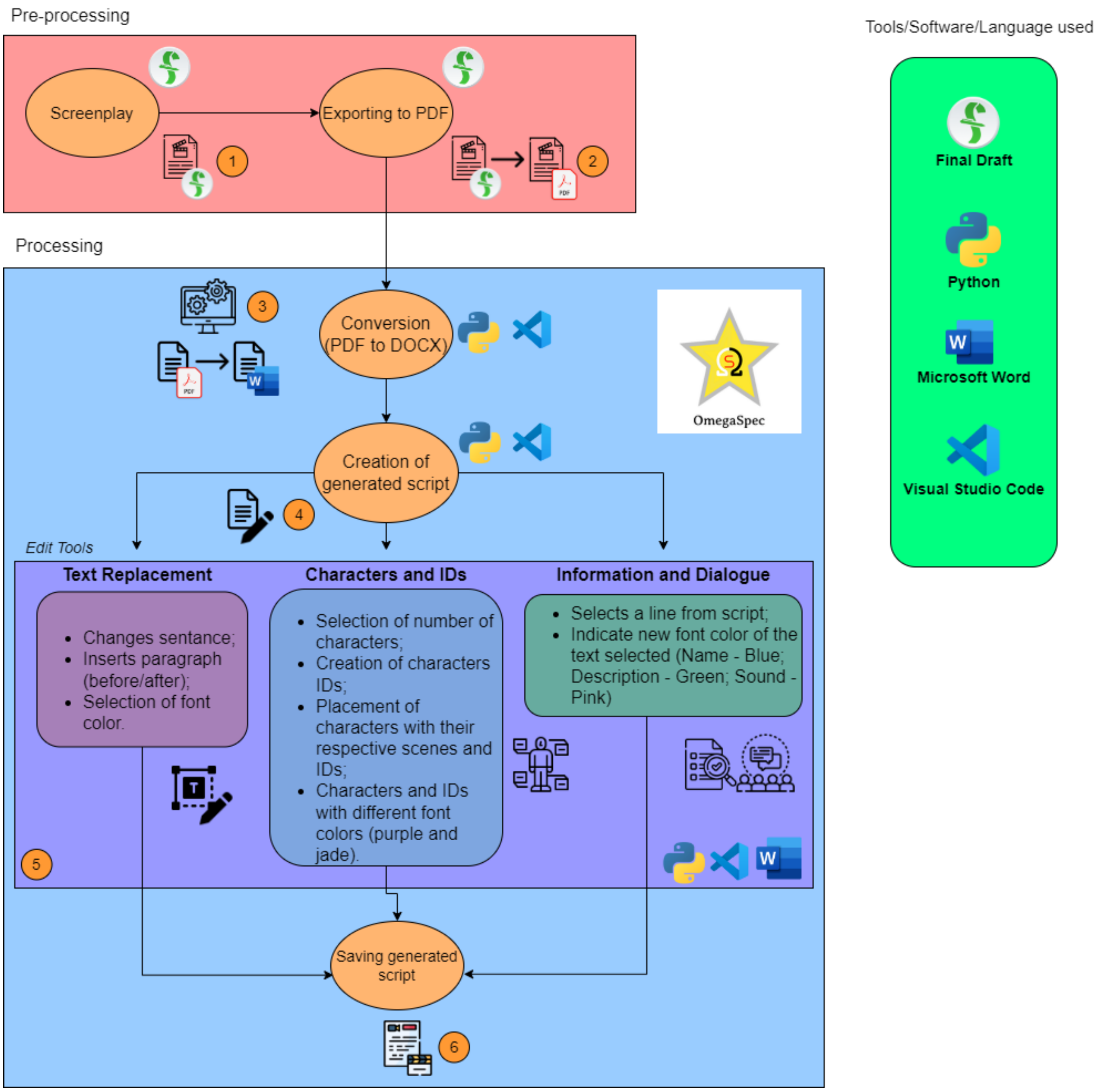


Figure 17: Schema of tools used and the construction of the script.

2.2.2 OmegaSpec: How it works

Before running the script, it's important to download the programs libraries in the terminal. Once they're downloaded, in the terminal, write *python OmegaSpec.py* or *python3 OmegaSpec.py* to start the program.

The program will ask if the users want to convert a **Portable Document Format** (PDF) into a **Microsoft Word Document** (DOCX).The documents and the script need to be on the same directory. If yes, then simply write in the terminal **yes, y** or **ye**, otherwise write anything to skip this section. Next, a message will pop up in the terminal to advise the user to make certain edits to the docx document before continuing, as this script follows certain patterns. In case they decide to exit the program, simply write in the terminal **no** or **n**, otherwise write anything to skip this section.

Regarding the editing of the select document, in the *View* options, select the ruler option (with inches), as this will help to identify the different sections of the movie script (**View** and select **Ruler**). Then to display the Inches option, go to **File** > **Options** > **Advanced**, scroll down to display, and in the *"Show measurements in units of"*, select **Inches**. With the ruler, pick a certain value for the text on the left (Information/Location) and the text on the middle (Characters/Dialogue) and make sure they follow the same pattern, otherwise the program won't be able to find all the useful information.

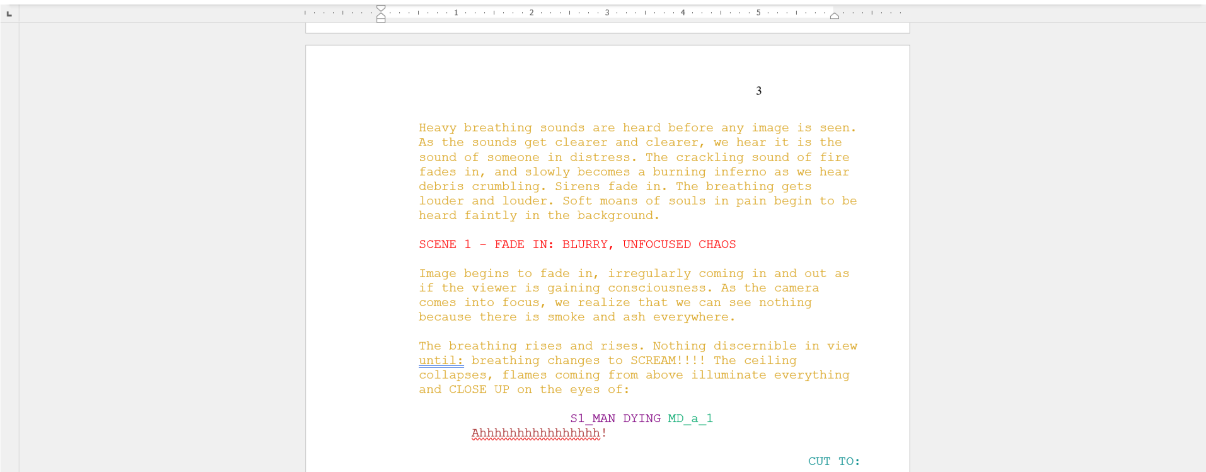


Figure 18: The ruler option in the Microsoft Word.

Once the document is fully edited to the user's liking, the program can continue. The OmegaSpec will read the entire script and change the font colors. The middle text is now brown, the left text is gold, the words "CUT TO:" will have a dark cyan color, and the text that includes FADE, INT., EXT. will have a red color and will add the word SCENE and it's respective number. The user has 4 options:

- *1-Edit Movie Script*;
- *2-Characters and Actions*;

- *3-Names, Descriptions and Sounds*;
- *4-Save and convert Script*.

By selecting **1**, the users need to select the number of inches (for this case, > Inches for the middle text, and < Inches for the left text), then it can insert/replace text with the following options: *1-Insert Paragraph Before*; *2-Replace Text*; *3-Insert Paragraph After* or *Skip*. Then the program will ask the font color for the new text (Red, Green, Blue, Pink, Brown, Gold, Dark Cyan, Purple, Jade, Black). Finally it will ask if they want to continue (yes) or leave (no).

By selecting **2**, the users need to select the number of inches (for this case, > Inches), and select how many characters the user wants to convert *(1, 2, 5, 10, 20)* or it can skip this section. The program will ask the name of the character in action and some letters/numbers for their IDs. The program will then replace the names with the letter *S*, an number associated with the current scene, the character *unserscore (_)* and the name (if a character has two names, it will replace the blank space to avoid potential error), and use the font color purple. Then right next to the character, the program will create an iD with the font color Jade (Example: Character - **S4_AKHEN**; Action ID - **RA_a_1**). Finally it will ask if they want to continue (yes) or leave (no).

By selecting **3**, the users need to select the number of inches (for this case, < Inches), then it can convert the text with the following options: *1-Regular Text*; *2-Character Names*; *3-Character Description*; *4-Sounds* or *Skip*. They must select the text within the line in order to convert it. If they try to select the whole paragraph, the program won't be able to convert it. Finally it will ask to continue (yes) or leave (no).

By selecting **4**, the program will convert the custom DOCX document into a PDF and the script will stop running.

2.3 Scriptsheet

2.3.1 What is Scriptsheet

Although it's important to create notes for the screenplay. such as names and descriptions, it's necessary to create a database that can store important data from the generated script.

A database is a collection of data that is organized in tables and stored on a computer system, where it can be updated or modified. The traditional term is database management system (DBMS). The DBMS provides programmers a defined process for data formation, handling, recovery and updating.

For this instance, Scriptsheet is a program that serves as a bridge between OmegaSpec and MovieBirth. In order to turn a screenplay into a movie, we need to gather all the information from the script (characters, scenes, IDs, time of day), chronologically, so that users can have easy access.

While there are many examples of database programs, such as MySQL, MongoDB, or MariaDB, the Scriptsheet program utilizes Microsoft Excel, as it is a best way to store data and to analyze it, and can use many free templates as we want to, in this project, we will use 3 tables which we'll explain in the next section.

One important note, while we're developing a movie the user needs to know the time when a scene occurs or when a character steps in. So with the help of Python's *text to speech*, the program, while reading the script line by line, every time it encounters a specific word, either a scene or a characters' ID, it will place a timestamp on the template, so that the user has a general idea on where it can place the characters and the environment on the timeline.

Text to Speech, sometimes referred as Speech synthesis, is a computer-generated human speech, that converts text into human-like speech audio. There are several APIs that can offer this service, like Google Text to Speech, Scriptsheet utilizes the **pyttsx3** library. Unlike most libraries, pyttsx3 works offline and it's compatible with both Python 2 and 3. It can support two voices, male and female, and three TTS engines: sapi5, nsss, and espeak.

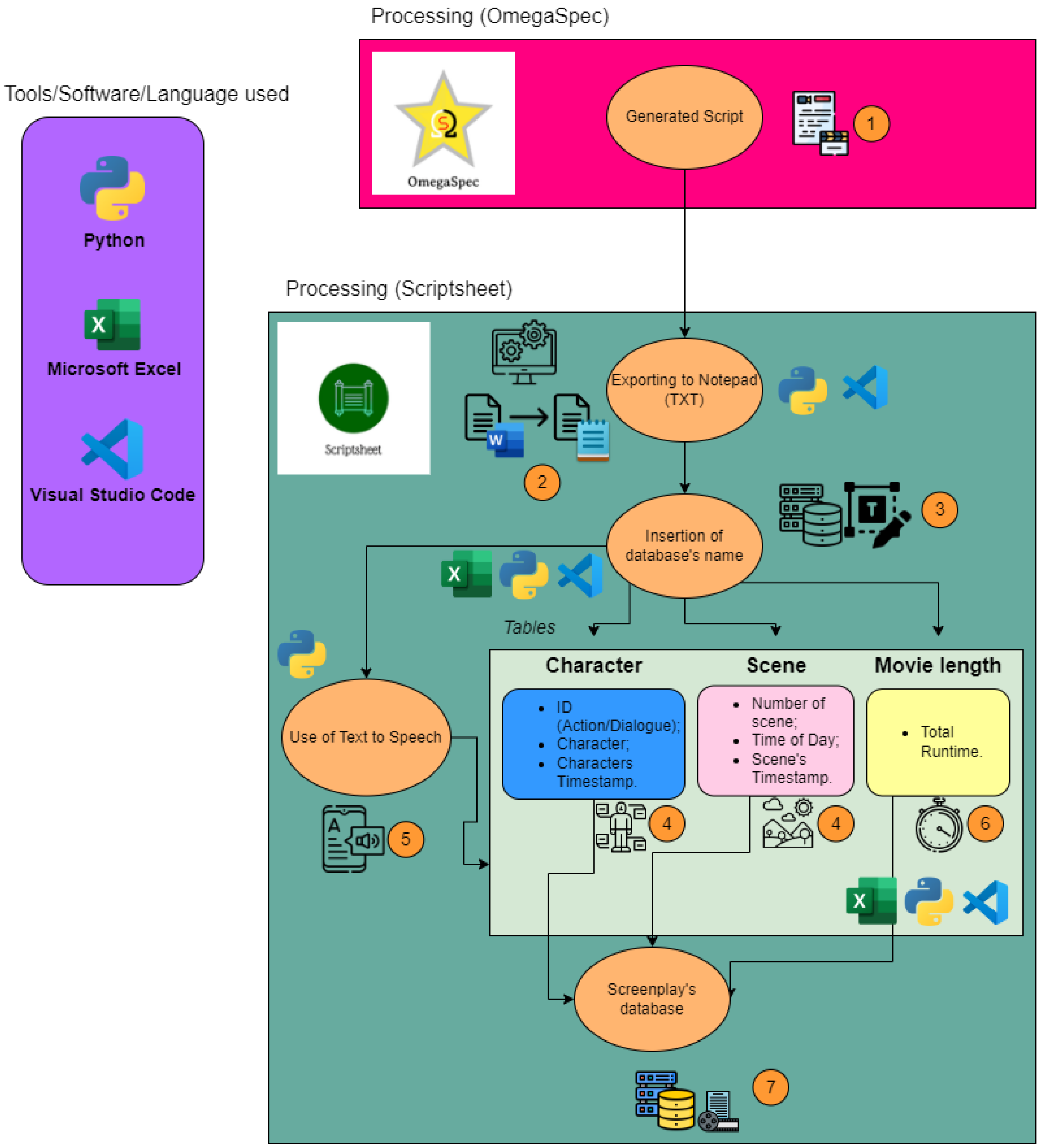


Figure 19: Schema of tools used and the construction of the screenplay's database.

2.3.2 Scriptsheet: How it works

Much like OmegaSpec, before running the python script, it's necessary to import the programs libraries in the terminal. When that is done, the user writes *python Scriptsheet.py* or *python3 Scriptsheet.py* in the terminal to begin.

It will then request if they want to change a **DOCX** into a **Notepad** (TXT). The files require to be on the same directory. To convert the file, the user simply writes in the terminal **yes, y** or **ye**, otherwise any character will skip this section. Next it will ask to insert a name so that it can create a **Microsoft Excel File** (XLSX/CSV). By doing this it will create a spreadsheet with 3 tables with the following columns:

Table 1 - Characters

- **Column A:** *Action/Dialogue*;
- **Column B:** *Character*;
- **Column C:** *Timestamp (Character)*.

Table 2 - Scenes

- **Column F:** *Scene*;
- **Column G:** *Time of Day*;
- **Column H:** *Timestamp (Locations)*.

Table 3 - Movie length

- **Column K:** *Total Runtime*.

The script will then use a *text to speech* tool to read the notepad (movie script) and everytime it reads a scene or a character's ID, the script will timestamp how long it took to locate the text. Once it's done, it will display the runtime of the program so that the user can known how long it took to read the entire movie script.

The Scriptsheet tool has currently been updated, where instead of placing a timestamp in seconds, it will now be displayed in hours:minutes:seconds.

2.4 MovieBirth

2.4.1 What is MovieBirth

When a movie maker edits raw video/footage, it can be in all types of projects, such as commercials, tv shows, and films. They also work with the director when editing and organizing the video footage to meet with the results of the overall insight for the project to improve the final product.

In the modern world, editors use linear editing software, such as Final Cut Pro or Wondershare Filmora, to edit, select, join and split content, and assist the syncing of raw footage and music to create the final product.

In regarding 3D computer graphics, it is essentially an image that uses computer software to create meshes/objects in three-dimensional environments. It can be performed by means of a dedicated program (Blender, 3ds Max, Maya, Cinema 4D).

MovieBirth is basically a addon/program that, by using Blender, takes the resources of the movie editing and the 3D computer graphics, and offers 4 tools to help the user to develop animated movies. Addons are essentially secondary scripts that extend and create new Blender features. While it's important to use this addon down the road, the user must first get used to Blender, as it is recommend to start out without them and only exploring them once the user has figured everything out. For instance, when making the environment and the characters, it's recommended to make new collections, and to import 3D models or making the model themselves (with an armature). Regarding the MovieBirth Tools, the user needs to insert frames throughout the timeline, and it is provided with the generated script (in this case for the subtitles), and the database that contains the timestamps for the character animations and dialogues, and the scene transitions. Although the user can simply turn on the Show Seconds option on the Blender timeline, the python program allows them to insert the number of seconds, and the program calculates the estimate frame value. For instance, 600 frames is the equivalent of 10 seconds, so for the frame range, which by default has the frame start at 1 and frame end is 250, if the user wants the frame start value, the number of seconds would be approximately 0.02 seconds, and for the frame end it would be approximately 4.17 seconds.

$$Y = \frac{600}{10}X$$

With a new version of Blender available to the public (Blender 3.2), the frame range can now only be in integer numbers instead of decimals, and the timeline has also change, so instead to 600 frames being equivalent of 10 seconds, it's now only 240 frames.

The Moviebirth tool was also updated, where instead of giving the number of seconds in decimals, the user now need to put the number of hours, minutes, seconds, and, being optional of course, extra additional frames between 0 to 23.

Hours:

$$Y = \frac{86400}{1}X$$

Minutes:

$$Y = \frac{1440}{1}X$$

Seconds:

$$Y = \frac{24}{1}X$$

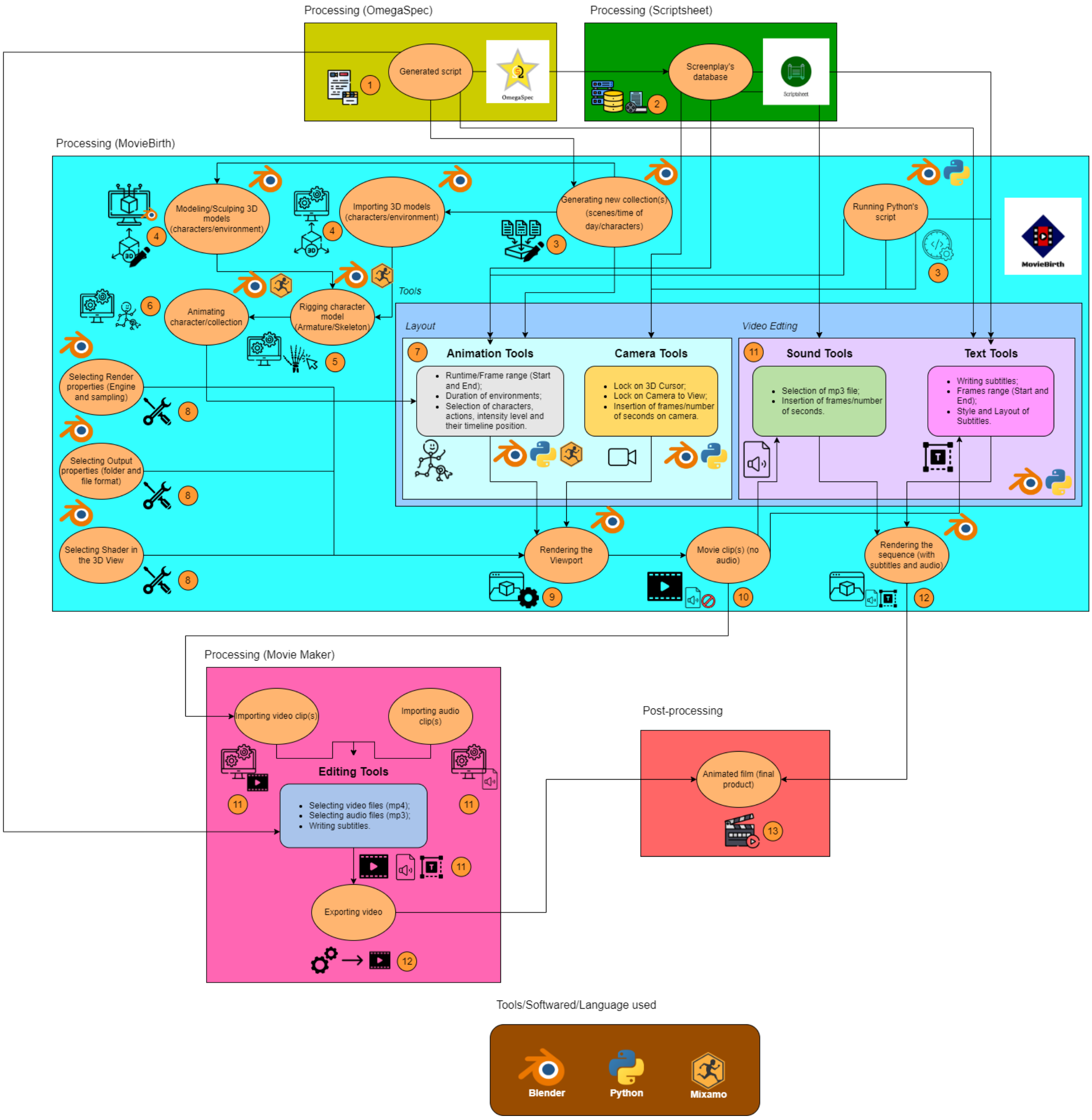


Figure 20: Schema of tools used and the construction of the animated movie.

2.4.2 MovieBirth: How it works

In the **Blender** application, the user needs to go to the *Scripting* workspace and open the **MovieBirth** script/addon, and run the program.

By clicking the letter N on the keyboard and selecting the MovieBirth window, the user will have access to 4 tools:

- *Animation Tools*;
- *Camera Tools*;
- *Sound Tools*;
- *Text Tools*.

In the Animation Tools, there are 3 buttons. The *Runtime: Start and End* will allow you to choose the frame range for the movie rendering. With the help from the spreadsheet created from the *Scriptsheet* program, the user can know the total runtime of the movie and insert the number of seconds, where in return they'll be converted into frames. The *Timeline* area display the frames, however if users want to see the actual time, simply go to **View** > **Show Seconds**. In *Biomes and Skydomes*, write the name of a collection (in this case the scenes or the time of day) and its range so that when there's a transition, the program will be able to tell the exact time where the collection will be visible/not visible. It's important to note that the users must right click on the mouse to select the collection, left click and select **Instance to Scene** because without this the user won't be able to animate the collection. In *Characters and Actions*, before using this tool, they need to change the names of the *armatures* for each character and apply an animation with the **Action Editor** and give it a name. The names need to be based on the generated script created from the *OmegaSpec* program (Example: Character - **S4_AKHEN**; Action ID - **RA_a_1**), however for this demonstration a character can have different animation depending on its level of intensity, so when naming the action, make sure you write _L and a number at the end (Example: **RA_a_1_L0**; **RA_a_1_L1**; **RA_a_1_L2**; **RA_a_1_L3**). Once that's done, they can write the name of the character, its action, its intensity level (0, 1, 2 or 3) and its position/frame in the timeline.

In the Camera Tools, there are 2 subpanels: the *View Lock*, by checking the **To 3D Cursor** and **Camera to View** and clicking the **Toggle Camera View** button, the camera can look at the cursor and enable the view navigation within the camera (to remove these options, simply uncheck and click the Toggle button); the *Frames* option can insert the frame of the camera from its position.

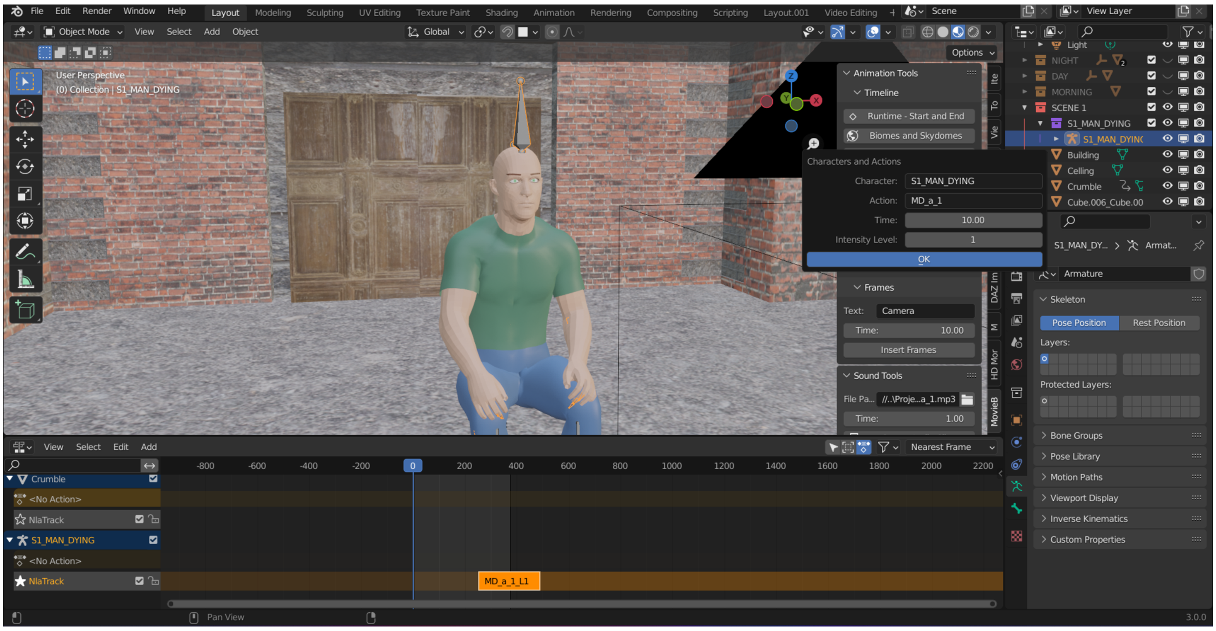


Figure 21: The Actions Tools and the Timeline workspace.

For the sound and text tools, select the *Video Editing* workspace, click on the plus mark on the top to add a workspace, **Video Editing** > **Video Editing**.

In Sound Tools, the user can insert an MP3 file and the timestamp to add sounds or dialogue in the movie.

In Text Tools, the user can write any text like titles and subtitles and choose its length with the time start and end options. This tool also has 2 additional subpanels: the *Style* option chooses the font size and color and the *Layout* selects the position of the text with the Location X/Y and Anchor X/Y.

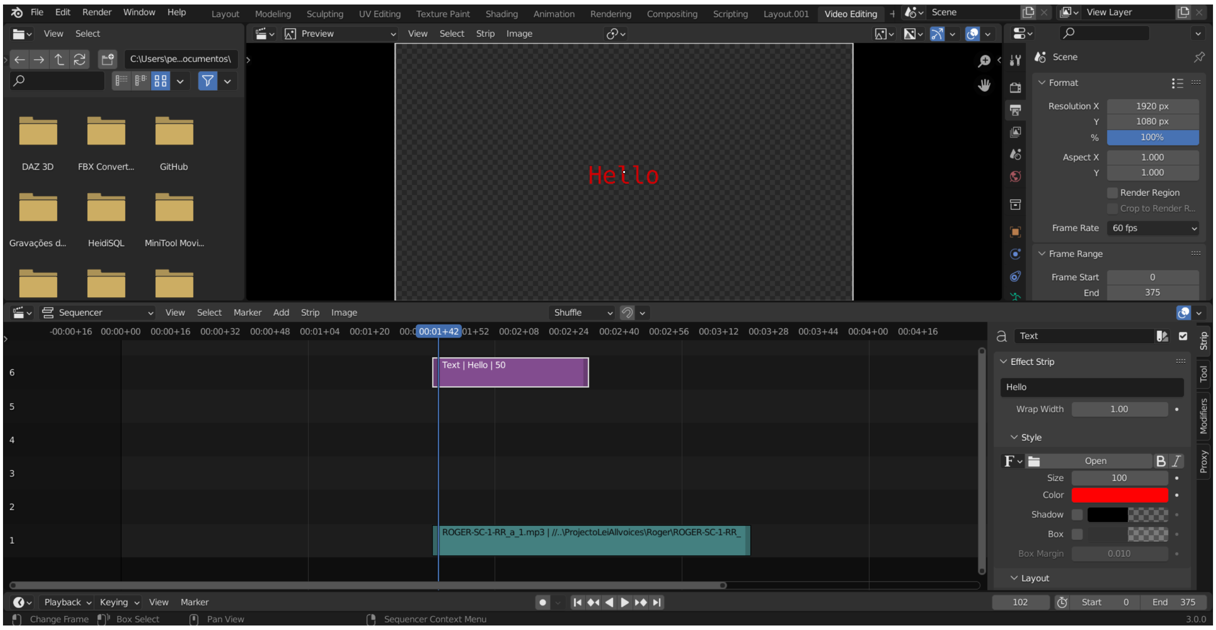


Figure 22: The Video Editing workspace.

2.4.3 Current apps

While one of the main objectives for this project is to market these three tools, it is important to keep changing, whether they can be used solely on editing and formatting screenplays, reading files, movie editing or sound making; analyze the current problems and how to resolve them; and understand the audience we are targeting.

- **Reading apps**: While some people prefer reading books traditionally, others don't want to keep books on shelves to occupy space and just simply want to read them and move on. Some new reading apps even come with new features, such as sampling titles which allows people to get a sample before buying the book. These are the current reading apps available on Google Play and the App Store:
  - *Amazon Kindle App*: Kindle gives people access to several books, magazines and newspapers, and gives free samples. It also free and allows to choose a font style and size;
  - *Libby by Overdrive*: It's free and taps into eBooks and audiobook titles;
  - *ReadEra*: It can handle books in all formats, such as pdf, docx, mobi, fb2. The navigation is intuitive and the reader can automatically find any compatible material on its device, and it doesn't have adds. It's currently free, although there's a premium version that unlocks extras;
  - *Wattpad*: It's currently one of the most popular eBook reading apps for beginners, being about simplicity, it's free, and allows readers to write and upload your own stories.
  - *Bookmate*: Gives the opportunity to browse through friend's bookshelves, and find new friends that have similar interests. The app also asks the user's favourite books and genres, allowing to personalize its reading experience.
- **Editing screenplay apps**: It's important for a screenwriter to choose an app that is reliable and user friendly. Regardless of the app, all screenwriting software takes care of formatting so that the writer can put words and create characters, the world and the story. Besides Final Draft, these are the major current apps available:
  - *WriterDuet*: A cloud-based screenwriting software. It combines natural process and user-friendliness so that writers can collaborate with each other, in real-time and in non-linear workflows. It has a free and a premium version.
  - *StudioBinder*: A free web-based application that is very mobile friendly. It also allows to collaborate with others in cloud. What makes this app so distinctive is the fact that the screenplay is connected to several planning tools.
  - *Arc Studio's Professional Screenwriting Software*: A free user-friendly screenwriting software that has a desktop version and includes a mobile version for premium users. It includes a user interface with minimal distraction, so writers only go for the story and the software takes care of the format.

- *Celtx Script*: A well-known app that has auto formats for screenplays, audioplays, and stageplays. The full product includes storyboarding, scheduling and budgeting.
- *Storyist*: It's very useful for novel-writing circles. It incorporates auto format for the script. It has manuscript templates and a batch of screenwriting features.

- **Sound Making apps**: Several digital audio workstations include features that focus on audio editing, but they're designed with the sole purpose of music production, helping to produce simple, yet professional-grade audio. These are the major current sound making apps available:
  - *Audacity*: One of the best free tools that rivals with premium paid-for programs, although, it's a development model made in an open source, it offers several attributes that can only be obtained with money. This tool adds a noise reduction, a tool that repairs something automatically, and a compressor. It also includes several formats that can be the imported/exported.
  - *Ocenaudio*: Offers an accessible entry-point for newcomers. It can add markers to files, edit specific channels and change the metadata before exporting. Like Audacity, it's a free open source editor tool, however, while Audacity offers limited tools and some find it overwhelming, Ocenaudio is great to edit large files without affecting performance.
  - *Acoustica*: Provides extra content than an average free audio editor. Acoustica can be used to edit and mix on waveform, both single-track and multi-track, and offers external plugins.
  - *Fission*: A Mac application that can regulate the audio, dim the clips, or even turn up certain parts, but doesn't have noise reduction, and plugins aren't supported. It also doesn't have multi-track editing or multiple inputs recording.
  - *Adobe Audition*: The best audio editor overall. Audition can edit with single-track and mix with multi-track. It also added audio restoration tools, which allows to remove noise, pops and clicks. Although it's not free, Audition is capable of polishing the finishing for standalone audio/video.

- **Movie Making apps**: Currently, video editing software are used to perform post-production video editing sequences on a non-linear editing system. By combining multiple recordings and arranging them in a particular order, and applying visual effects or color correction are the reasons why these programs are popular. These are the major current movie making apps available:
  - *Wondershare Filmora*: It features a rich selection of free music and audio effects to create soundtracks for videos. It also offers 4K videos support. While it can be bought for free, it's necessary to buy a subscription to gain access of all the features it offers.
  - *Windows Movie Maker*: It allows editors to capture new footage or process the pre-recorded videos. It was also equipped with several animations (transitions, credits). It was discontinued in 2017.

- *Film Maker Pro*: Allows to cut, split, duplicate, and detach audio from a video.
- *Quik*: It has AI technology that detects different emotions from a gallery.
- *Splice*: Allows to use desktop-like functions on a mobile app. Has several editing options (effects, text, transitions). It's only available on IOS.

3 Movie in development

Key points:

- Explaining the creation of the characters, how they were rigged, and the making of the environments;
- Explaining the making of the special effects;
- The use of the MovieBirth tool for the framing of the scenes, actions and the camera position in the timeline;
- Showing the incorporation of the audio files and subtitles when rendering the final product.

After having all tools implemented, reading the entire screenplay with all the characters descriptions and the environments, we can then begin making the movie based on the script that was given. In this section, we will focus on the making of the movie "Peace Wars", specifically, how the 3D models were made, how they were rigged, the steps that were made to create an action for each character, the making of the environments and skydomes for the scenes, the effects added for certain scenes, the positioning of each action in the timeline, and finally the rendering of the final product with the audio and subtitles included.

Regarding to the character making, the 3D models are generated based on the information that was given in the screenplay, such as its gender, clothing, height, skin color and hair, and so on. With a blank model, we added other meshes for the eyeballs and other body parts, and used the duplicate function for the clothing, eyebrows, eyelashes, and hair. While some models were made from scratch, some outfits like the space suits and helmets were imported into Blender, and redesigned to fit into the characters. Lastly, we used the shade smooth function to make the models look more "normal".

Once a character is created, we export it as a FBX file with **File ->** **Export ->** **FBX** with no rigging.

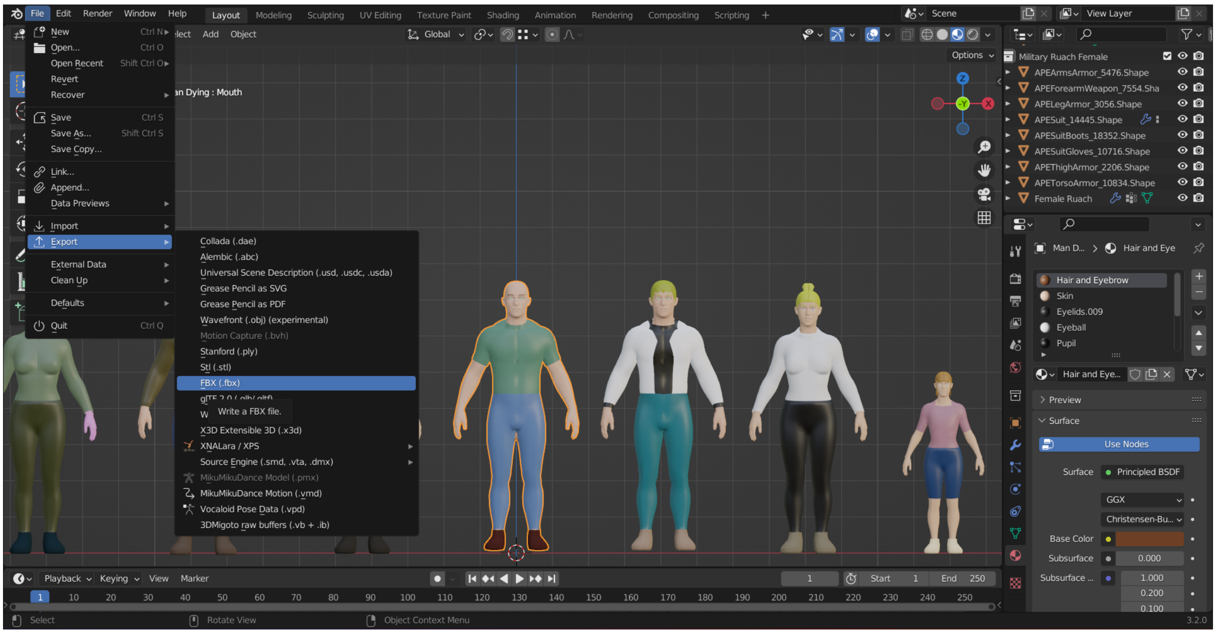


Figure 23: The making of 3D characters based on the screenplay.

In order for the models to perform several actions in Blender, we will need to rig them. Although Blender offers the tools to create an armature, it can be very monotonous, mainly due to the fact we need to input the weight on each bone, and this film has several characters. Luckily, Mixamo has a auto rigging process, where we simply upload a 3D model, and program will ask the user to place markers on the model, that includes the chin, wrists, elbows, knees, and the groin. It also includes different versions of the autorigger skeleton to optimize performance. Once it's done, we simply click Next, and program will start the auto rigging. Mixamo also contains a library with several characters and animations that anyone can use for their movie clips. Finally, the user can click on the Download button to export a FBX file with its character rigged.

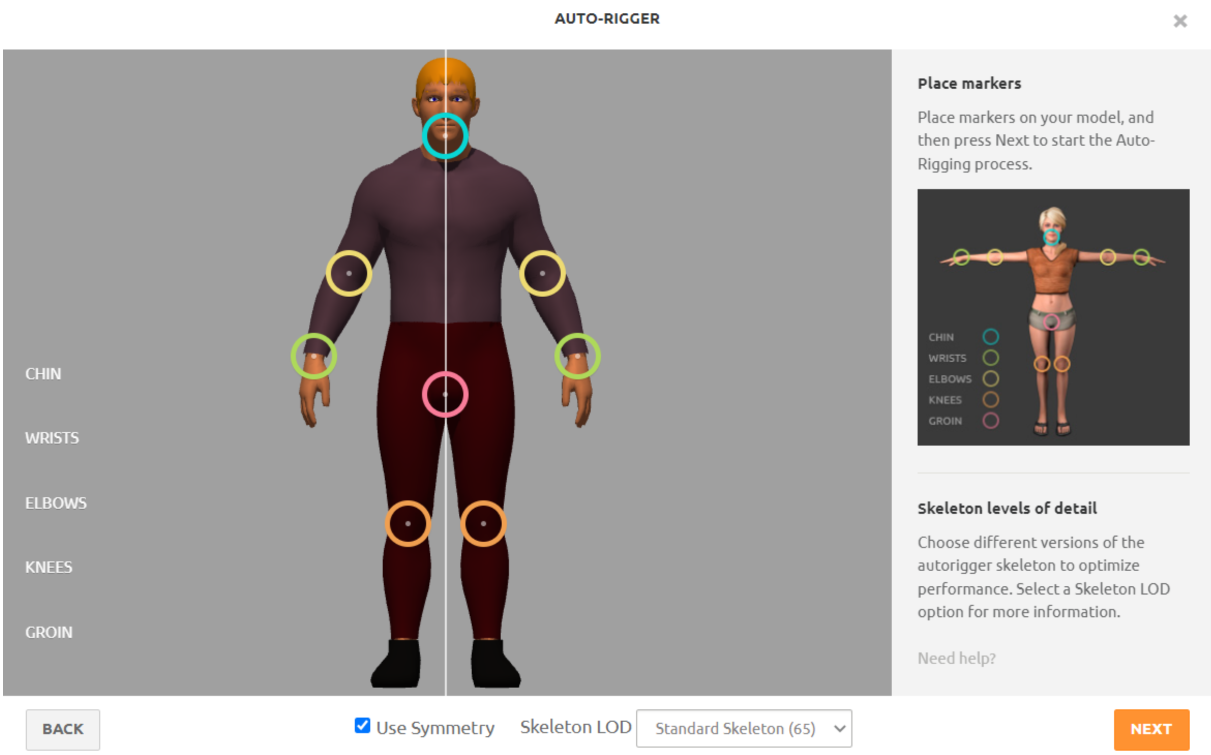


Figure 24: Rigging a 3D model with Mixamo.

After the rigging, we then import the model with the Blender file specifically made for the movie. With the screenplay, we change the armature's default name into the new name that is present in the script, for instance S4_AKHEN, and we move the skeleton and the meshes inside a collection, which in this case would be SCENE 4. Furthermore, with the **Action Editor**, we click on the New button to create an action, or if the user gets a Mixamo animation then it doesn't need to create an action, select the bones from the armature, use the move and rotate function, and click on the Key I to open the Insert Keyframe Menu. Once the action is complete, the user needs to click on the Push Down button to push the action down on the NLA stack as a new strip.

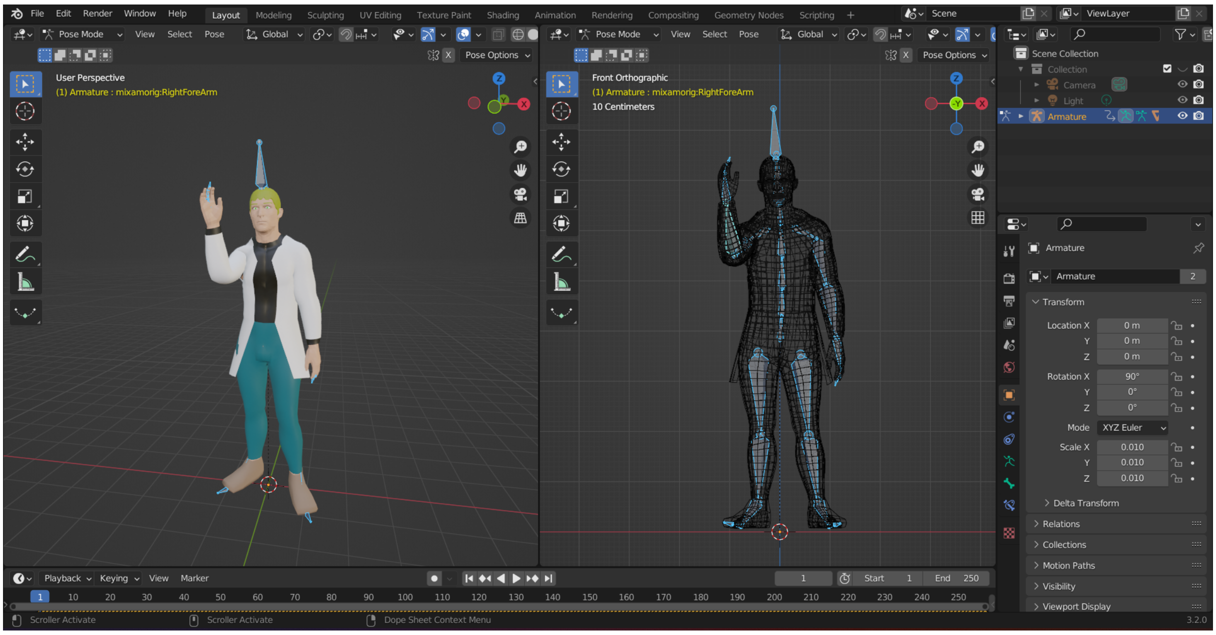


Figure 25: Making poses with the model's armature.

Regarding to the environments, like it was previously mentioned, they were split in two section: Biomes and Skydomes. Like the characters, once the objects/meshes are constructed/imported, we move then to new collections. For this project, the skydomes collections are orange and are named after the time of day (DAY, NIGHT, MORNING, AFTERNOON), while the biomes collections are red with the name SCENE and its specific number.

For the skydomes, we simply add a UV sphere mesh where it's cut in half and scaled to a reasonable size, and with the help of the UV Editing workspace, we insert a texture to "recreate" the sky, where for instance we added clouds, the sun, the moon and even fog.

For the biomes, first we add the floor with a planar mesh and its texture (grass, dirt, rocks), and then by importing/making 3D models such as buildings, roads, trees, houses, cars, oceans, and so on, we create the environments for each scene and give life to our world.

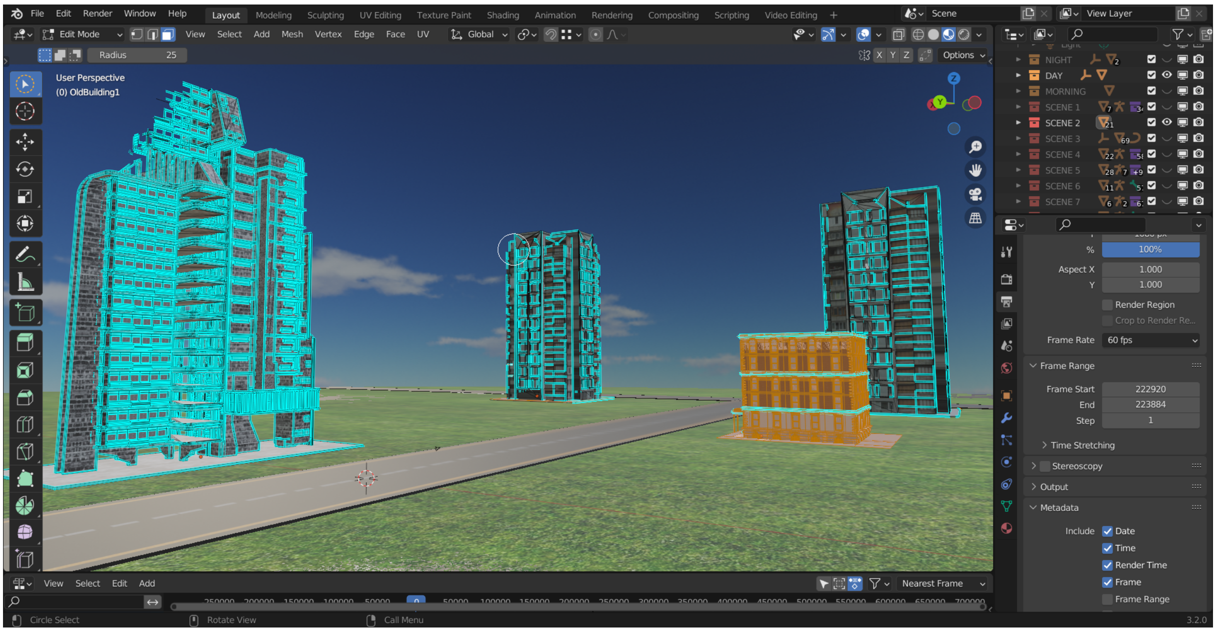


Figure 26: Editing the city from scene 2.

For instance, scene 17 was the first scene to be made during the movie's development, and so we took the liberty to make the objects as "realistic" as possible. The scene starts with Akhen and his family in the kitchen, and by taking inspiration of the modern world, by observing its references, we were able to recreate in Blender, as well as to make materials for each object. For example, we added a metallic surface on the fridge and glass on the window that reflects the lighting into the room.

Figure 27: Editing the kitchen from scene 17.

Regarding to the special effects, as we can see in Figure 28, we added a wave modifier to simulate the flames in the spaceships' thrusts, as well as the particle system for the lasers.

The Wave modifier puts a ripple-like motion to the object's geometry, being available for meshes, surfaces, curves, and even texts. Particles usually disperse from the object into the open area, and their motion can be influenced by the initial acceleration out from the object, the movement according to gravity an the emitter itself, colliding with other existing meshes, smooth motion with soft body physics, and so on. The usual process to work with these particles is to make the object that will release the particles, generate one or more from the object, change each settings to accomplish the correct result, animate the base object and other particle that are related, define and format the movement of the particles, and simulate its physics and make a final render.

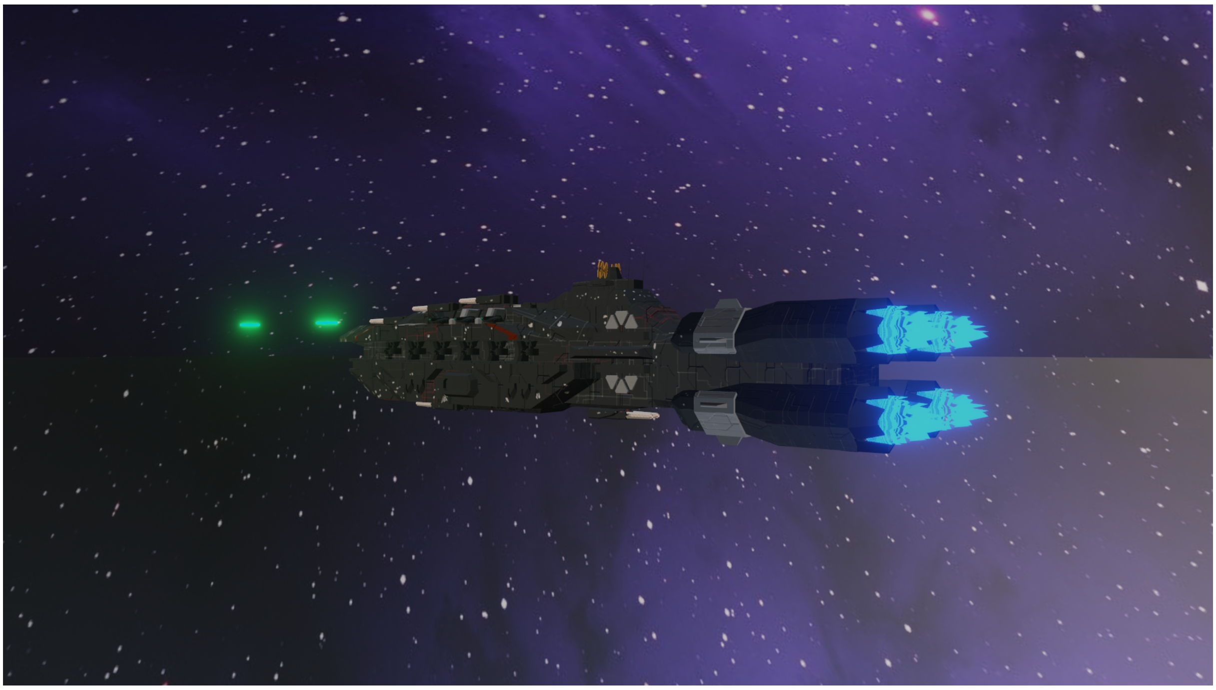


Figure 28: A spaceship with special effects.

Once the actions show up on the NLA stack as a new strip, we can manipulate and repurpose actions, without handling keyframes. This editor can also chain together a sequence of motions, which makes it easier to organize the animation. The tracks are the layering system of this editor, and can help organize strips and can layer motion similar to how an image editor layers pixels.

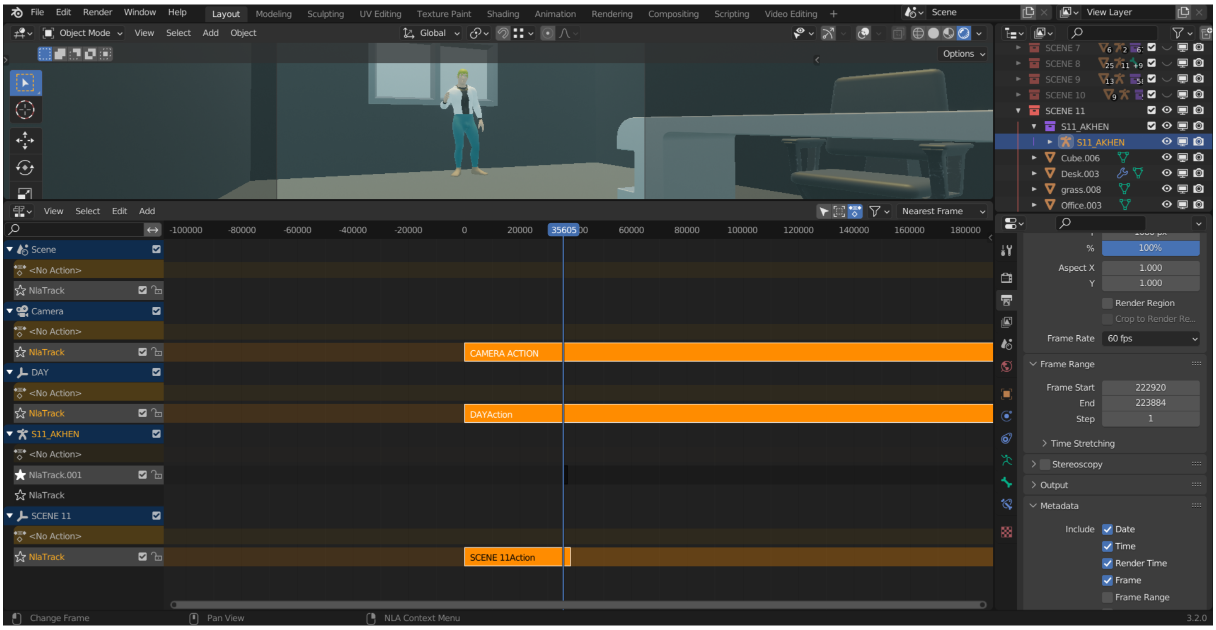


Figure 29: Editing the frames in the Timeline.

Finally, once we had the full movie without the audio, we used the Video Editing workspace to include all the sound files provided, as well as the subtitles, and once it as all done, we simply clicked on the **View -> Sequence Render Animation** to get the final product.

While Blender is mainly used for modeling and animation, it can also help users to edit videos. Blender's Video Editing like any other editing tool allows to combine multiple video channels and add any effect to construct very creative videos edits.

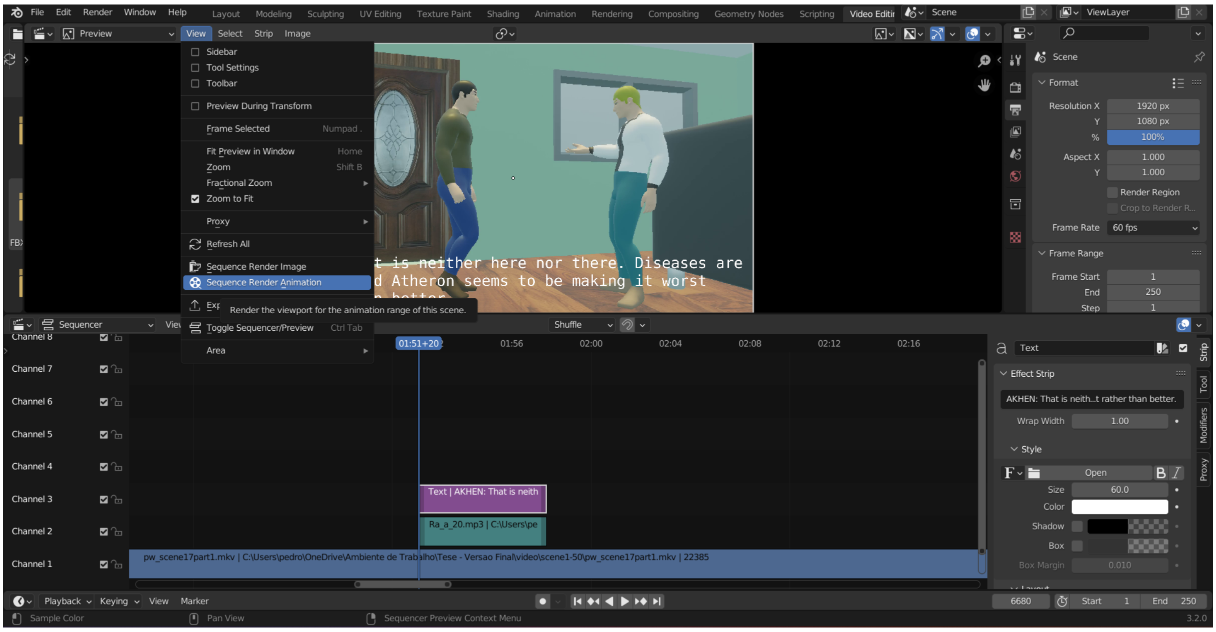


Figure 30: Adding movie clip, audio clips, and subtitles to render the final product.

4 Results

Key points:

- To explain the different formats used for this project, and to demonstrate the differences in the engines (Eevee and Cycles), and the shaders (Material Preview and Rendered);
- The results obtained in this section will demonstrate how can we improve the rendering quality in Blender.

The results for this project were obtained with two .blend files: one with 50 scenes/collections, and the other with all the scenes in the movie script (166 scenes/collections). For both files, it was created a small python program that can insert the time/frames for a respective scene and count the number of seconds it took for the viewport render animation. All the timestamps are saved in a notepad file. For this project, the python program rendered the first 20 scenes of the movie in the following formats:

- **Eevee (Material Preview)**;
- **Eevee (Rendered)**;
- **Cycles (Rendered)**.

Eevee and Cycles are the **two main rendering engines** for *Blender*. Eevee being a **real-time rendering engine**, can render extremely fast so it is often used as a preview engine in the viewport, however being a real-time rendering engine means that users can't expect the best quality/realistic renders. Cycles, unlike Eevee, is a physically based rendering engine, in other words, it tries to match the real world physics **(Shadows, Lighting, Reflections)**, and while the results looks far more accurate than Eevee, it can take more time to render. While Cycles doesn't offer a lot of settings, one useful thing to decrease the rendering time is to turn on **Denoising** (preferably with a Nvidia GPU), as this allows to render less samples while still getting rid of a noise. However this comes with a drawback, as this could lose some small details.

Regarding the Viewport Shading, Material Preview and Rendered are shading modes that can be adjusted to match the assigned work. The Material Preview mode is particularly suited for previewing materials and texture painting. It also renders the 3D Viewport with Eevee and an HDRI environment. To test the materials, the user can select different lighting conditions (Scene Lights, Scene World (HDRI Environment, World Opacity, Blur)). There's also a Render Pass, which is useful to analyze and debug geometry, materials and lighting. The Rendered mode renders the 3D Viewport with the scene Render Engine. This mode also uses Render Pass.

Once the python program is finished, we then run the *IBM SPSS Statistics* software to create scatter plot graph with the timestamps from scenes 1 to 20, and analyse the values obtained for each model. The X axis is the duration of the movie clip for a scene, and the Y axis is the duration of the viewport rendering for a scene.

Inserted/Removed Variables[a]

Model	Inserted variables	Removed variables	Method
1	Duration of movie clip[b]	.	Input

a. Dependent variable: Eevee (Material Preview)

b. All requested variables entered.

Model	Inserted variables	Removed variables	Method
1	Duration of movie clip[b]	.	Input

a. Dependent variable: Eevee (Rendered)

b. All requested variables entered.

Model	Inserted variables	Removed variables	Method
1	Duration of movie clip[b]	.	Input

a. Dependent variable: Cycles (Rendered)

b. All requested variables entered.

Figure 31: Inserted/Removed Variables.

For all models, we will use the following timestamps for the X axis (the duration of a scene). As it was mentioned in section 2, these were obtained with the Scriptsheet tool.

Table Runtime of scenes 1 - 20.

Scene Runtime		
Scene	Length (HH:MM:SS)	Length (Seconds)
SCENE 1	00:00:36	36
SCENE 2	00:00:20	20
SCENE 3	00:00:54	54
SCENE 4	00:01:38	98
SCENE 5	00:01:08	68
SCENE 6	00:00:57	57
SCENE 7	00:00:27	27
SCENE 8	00:00:29	29
SCENE 9	00:01:22	82
SCENE 10	00:00:48	48
SCENE 11	00:00:50	50
SCENE 12	00:00:45	45
SCENE 13	00:00:23	23
SCENE 14	00:00:19	19
SCENE 15	00:00:07	7
SCENE 16	00:02:48	168
SCENE 17	00:06:13	373
SCENE 18	00:01:14	74
SCENE 19	00:00:13	13
SCENE 20	00:00:10	10

For the first .blend file (scene 1 to 50), there are a few number of collections and objects unlike the second .blend file, that has the first 50 scenes, plus 116 new scenes. Regarding the options, in Eevee, the sampling for viewport was reduced to 1 and Viewport Denoising was turned off, while in cycles, the device is opperating with GPU Compute (CUDA, NVIDIA GrForce GTX 1660 Ti) instead of with CPU, with denoise turned on (Denoiser - OptiX; Passes - Albedo and Normal) and the sampling for viewport was reduced to 1 . For both engines, the format of the scene's resolution is 1920x1080 with a frame rate of 60fps.

Table Runtime of scenes 1 - 20 with 50 collections.

Scene Runtime (seconds) - 1 - 50			
Scene	Eevee Material Preview	Eevee Rendered	Cycles Rendered
SCENE 1	665	649	540
SCENE 2	358	376	319
SCENE 3	3149	3445	834
SCENE 4	1780	1712	1429
SCENE 5	1529	1582	1001
SCENE 6	992	973	812
SCENE 7	527	511	385
SCENE 8	527	491	406
SCENE 9	1536	1424	1152
SCENE 10	902	837	676
SCENE 11	930	844	705
SCENE 12	836	727	640
SCENE 13	410	350	320
SCENE 14	359	309	277
SCENE 15	168	147	105
SCENE 16	3828	3538	2333
SCENE 17	7600	7386	5193
SCENE 18	1700	1643	1070
SCENE 19	247	215	191
SCENE 20	198	171	148

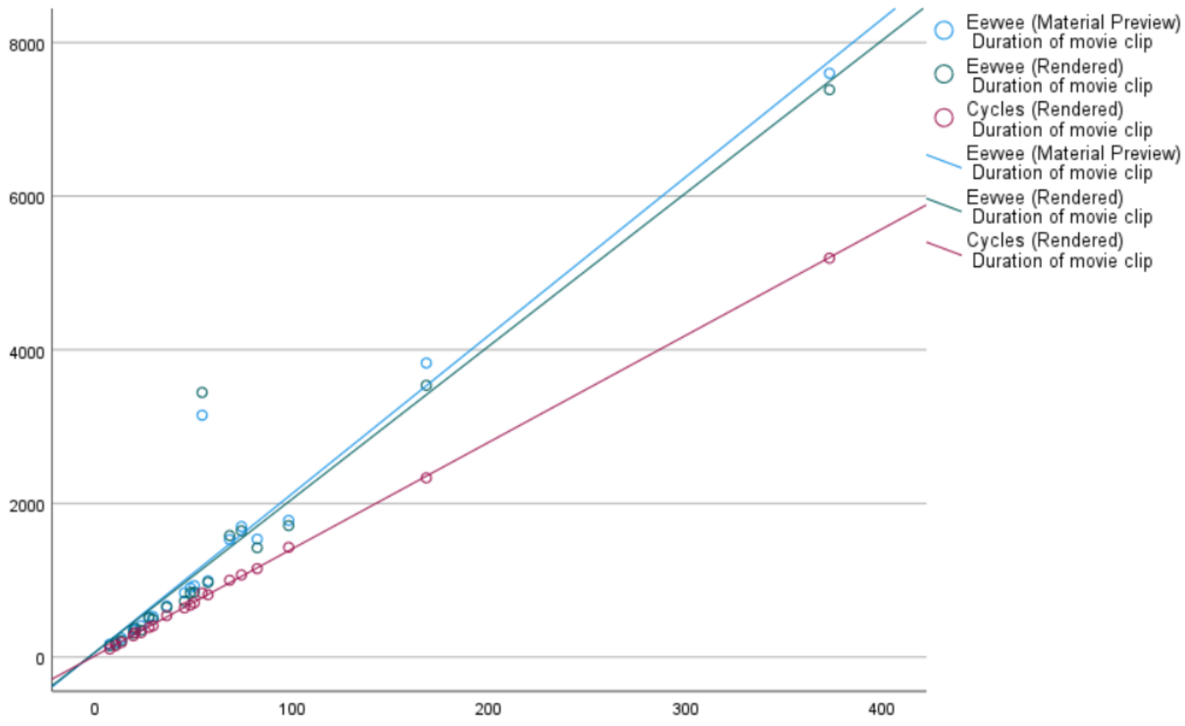


Figure 32: Scatter plot graph for the Viewport Render Animation with 20 scenes (Blender file with 50 collections).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.961[a]	.924	.920	494.043

a. Predictors: (Constant), Duration of movie clip

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	53726932.838	1	53726932.838	220.121	<.001[b]
	Residual	4393414.112	18	244078.562		
	Total	58120346.950	19			

a. Dependent Variable: Eevee (Material Preview)

b. Predictors: (Constant), Duration of movie clip

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	72.083	142.691		.505	.620
	Duration of movie clip	20.599	1.388	.961	14.836	<.001

a. Dependent Variable: Eevee (Material Preview)

Figure 33: Regression Data (Blender file with 50 collections): Model Summary; New Model with Regression, Residue and Total; Coefficients (Non-standardized and Standardized) - Eevee (Material Preview).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.946[a]	.895	.890	570.533

a. Predictors: (Constant), Duration of movie clip

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	50161770.587	1	50161770.587	154.103	<.001[b]
	Residual	5859140.413	18	325507.801		
	Total	56020911.000	19			

a. Dependent Variable: Eevee (Rendered)

b. Predictors: (Constant), Duration of movie clip

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	71.755	164.783		.435	.668
	Duration of movie clip	19.904	1.603	.946	12.414	<.001

a. Dependent Variable: Eevee (Rendered)

Figure 34: Regression Data (Blender file with 50 collections): Model Summary; New Model with Regression, Residue and Total; Coefficients (Non-standardized and Standardized) - Eevee (Rendered).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000[a]	1.000	1.000	24.448

a. Predictors: (Constant), Duration of movie clip

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	24409722.822	1	24409722.822	40840.266	<.001[b]
	Residual	10758.378	18	597.688		
	Total	24420481.200	19			

a. Dependent Variable: Cycles (Rendered)

b. Predictors: (Constant), Duration of movie clip

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	23.609	7.061		3.344	.004
	Duration of movie clip	13.885	.069	1.000	202.090	<.001

a. Dependent Variable: Cycles (Rendered)

Figure 35: Regression Data (Blender file with 50 collections): Model Summary; New Model with Regression, Residue and Total; Coefficients (Non-standardized and Standardized) - Cycles (Rendered).

For the second file (scene 1 to 166), all the scenes are available. Regarding the options, in Eevee, the sampling for viewport has 16 frame samples and Viewport Denoising is turned on, while in cycles, the device is still opperating with GPU Compute, and the sampling for viewport has 32 frame samples.

Table Runtime of scenes 1 - 20 with 166 collections.

Scene Runtime (seconds) - 1 - 166			
Scene	Eevee Material Preview	Eevee Rendered	Cycles Rendered
SCENE 1	1027	1058	864
SCENE 2	776	690	466
SCENE 3	3793	3946	1308
SCENE 4	2789	3114	2428
SCENE 5	2328	2409	1672
SCENE 6	1588	1662	1369
SCENE 7	805	806	688
SCENE 8	814	836	709
SCENE 9	2325	2590	2023
SCENE 10	1383	1583	1186
SCENE 11	1436	1640	1149
SCENE 12	1272	1323	1035
SCENE 13	640	655	527
SCENE 14	563	570	454
SCENE 15	250	255	175
SCENE 16	5691	6258	3851
SCENE 17	11818	12331	8716
SCENE 18	2755	3027	1767
SCENE 19	424	481	323
SCENE 20	327	377	255

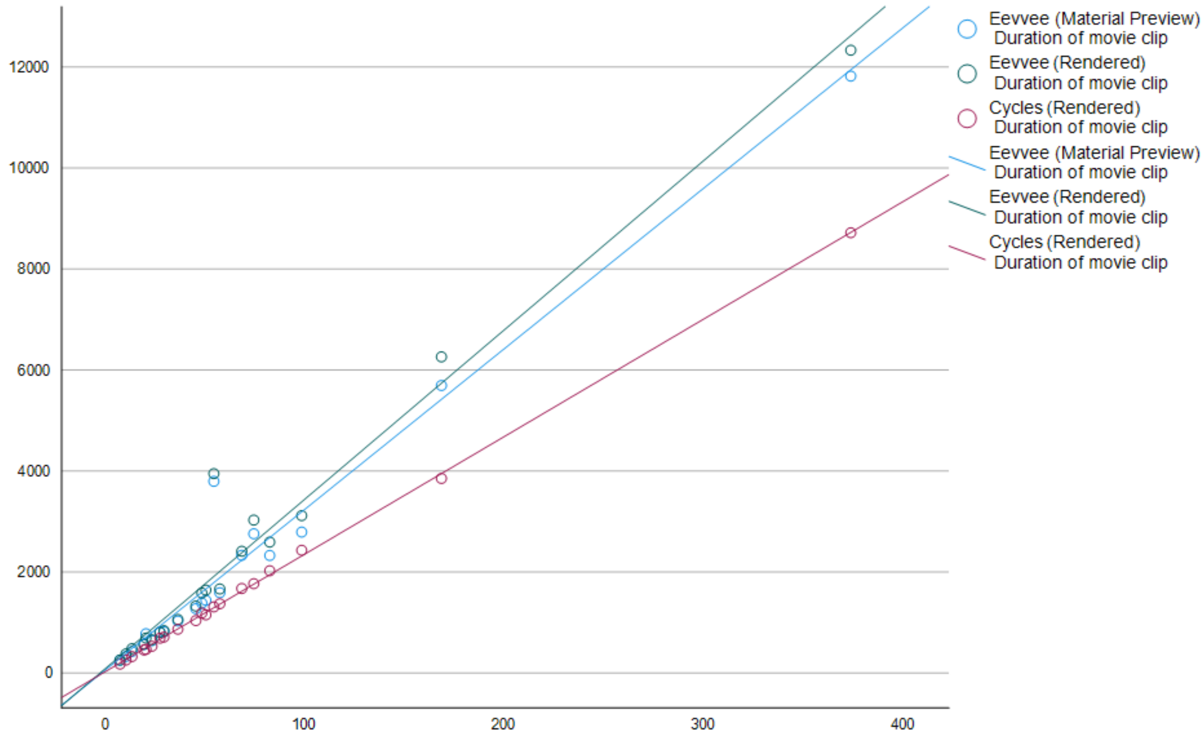


Figure 36: Scatter plot graph for the Viewport Render Animation with 20 scenes (Blender file with 166 collections).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.981[a]	.963	.961	520.931

a. Predictors: (Constant), Duration of movie clip

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	128297258.427	1	128297258.427	472.778	<.001[b]
	Residual	4884642.773	18	271369.043		
	Total	133181901.200	19			

a. Dependent Variable: Eevee (Material Preview)

b. Predictors: (Constant), Duration of movie clip

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	69.550	150.457		.462	.649
	Duration of movie clip	31.832	1.464	.981	21.743	<.001

a. Dependent Variable: Eevee (Material Preview)

Figure 37: Regression Data (Blender file with 166 collections): Model Summary; New Model with Regression, Residue and Total; Coefficients (Non-standardized and Standardized) - Eevee (Material Preview).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.982[a]	.964	.962	543.898

a. Predictors: (Constant), Duration of movie clip

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	142659636.149	1	142659636.149	482.244	<.001[b]
	Residual	5324842.801	18	295824.600		
	Total	147984478.950	19			

a. Dependent Variable: Eevee (Rendered)

b. Predictors: (Constant), Duration of movie clip

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	97.074	157.091		.618	.544
	Duration of movie clip	33.566	1.529	.982	21.960	<.001

a. Dependent Variable: Eevee (Rendered)

Figure 38: Regression Data (Blender file with 166 collections): Model Summary; New Model with Regression, Residue and Total; Coefficients (Non-standardized and Standardized) - Eevee (Rendered).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000[a]	.999	.999	48.346

a. Predictors: (Constant), Duration of movie clip

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	68727357.381	1	68727357.381	29403.917	<.001[b]
	Residual	42072.369	18	2337.354		
	Total	68769429.750	19			

a. Dependent Variable: Cycles (Rendered)

b. Predictors: (Constant), Duration of movie clip

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	32.726	13.964		2.344	.031
	Duration of movie clip	23.298	.136	1.000	171.476	<.001

a. Dependent Variable: Cycles (Rendered)

Figure 39: Regression Data (Blender file with 166 collections): Model Summary; New Model with Regression, Residue and Total; Coefficients (Non-standardized and Standardized) - Cycles (Rendered).

As we can see, despite the fact Eevee renders in real-time, due to the amount of meshes/objects that exist in the Scene World, it causes an delay to render each frame. For example scenes 2, 3, 4 and 5 take place in the same environment, but in scene 3 there are in total 48 characters so it would take more time to render a frame. In the 1 - 50 file, each frame took at most 0.5 seconds while each frame for scene 3 took between 1 and 2 seconds. For the most part, Cycles is much slower that Eevee, however for this project, while using an Nvidia GPU with Denoise turned on (OptiX), rendering each scenes was faster. Althought there is a downside. In Blender 3.0 when using Viewport Render with Cycles (Rendered), the output will be in black, thus making it hard to create movie clips.

When comparing both graphs, the one with 166 scenes took more time to render the scenes, due to not only having more meshes/objects, but because the sampling for eevee and cycles in viewport was at 16 and 32, being the default, while in the first graph, both samples were at 1. The render samples are what impacts the final render, therefore more samples mean less noise in the render, but more time to render each frame.

Next we will use a VMware Virtual Platform, and instead of using Windows, for this Virtual Machine, we will use Ubuntu 20.04.03 LTS. For this example, we utilized the first blender file (1 - 50), with the same preferences, however, because this Virtual Machine doesn't have a GPU, the Cycles Render Device will be none.

Table Runtime of scenes 1 - 20 - Ubuntu VirtualBox.

Scene Runtime (seconds) - 1 - 50 Ubuntu VirtalBox			
Scene	Eevee Material Preview	Eevee Rendered	Cycles Rendered
SCENE 1	10770	6381	2992
SCENE 2	7888	5867	1655
SCENE 3	19411	12751	4420
SCENE 4	31088	19105	8052
SCENE 5	21194	12898	5584
SCENE 6	16448	9583	4745
SCENE 7	8448	5121	2315
SCENE 8	8917	5419	2457
SCENE 9	24526	14534	6742
SCENE 10	14135	8230	4007
SCENE 11	14438	8452	4200
SCENE 12	13047	7683	3704
SCENE 13	6150	3340	1884
SCENE 14	5082	2665	1694
SCENE 15	2194	1237	694
SCENE 16	51284	30646	13628
SCENE 17	114302	67378	30151
SCENE 18	24995	15771	6112
SCENE 19	4209	2918	1174
SCENE 20	3501	2238	917

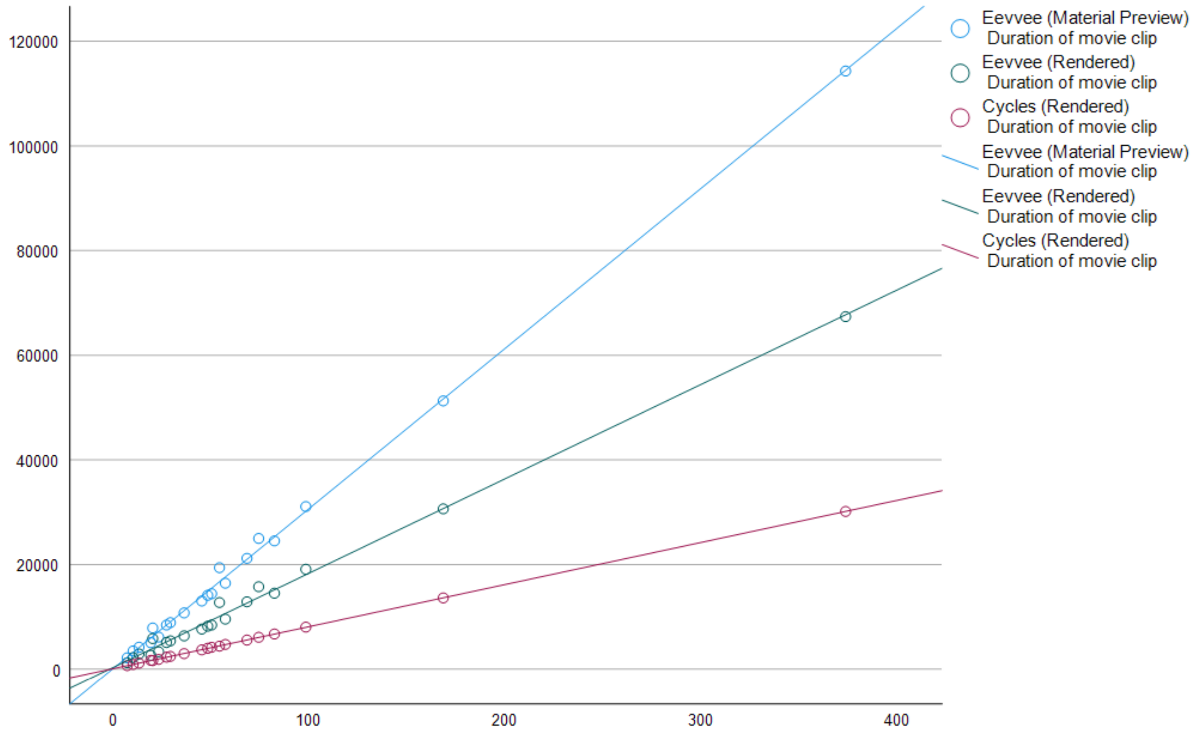


Figure 40: Scatter plot graph for the Viewport Render Animation with 20 scenes (Blender file with 50 collections) on a Ubuntu VirtualBox.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[a]	.998	.998	1109.362

a. Predictors: (Constant), Duration of movie clip

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11886814664.745	1	11886814664.745	9658.702	<.001[b]
	Residual	22152321.805	18	1230684.545		
	Total	11908966986.550	19			

a. Dependent Variable: Eevee (Material Preview)

b. Predictors: (Constant), Duration of movie clip

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	170.276	320.410		.531	.602
	Duration of movie clip	306.396	3.118	.999	98.279	<.001

a. Dependent Variable: Eevee (Material Preview)

Figure 41: Regression Data (Blender file with 50 collections) Ubuntu VirtualBox: Model Summary; New Model with Regression, Residue and Total; Coefficients (Non-standardized and Standardized) - Eevee (Material Preview).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.997[a]	.994	.994	1126.995

a. Predictors: (Constant), Duration of movie clip

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4130637352.552	1	4130637352.552	3252.169	<.001[b]
	Residual	22862115.998	18	1270117.555		
	Total	4153499468.550	19			

a. Dependent Variable: Eevee (Rendered)

b. Predictors: (Constant), Duration of movie clip

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	361.699	325.503		1.111	.281
	Duration of movie clip	180.617	3.167	.997	57.028	<.001

a. Dependent Variable: Eevee (Rendered)

Figure 42: Regression Data (Blender file with 50 collections) Ubuntu VirtualBox: Model Summary; New Model with Regression, Residue and Total; Coefficients (Non-standardized and Standardized) - Eevee (Rendered).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000[a]	1.000	1.000	40.023

a. Predictors: (Constant), Duration of movie clip

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	821467659.967	1	821467659.967	512837.081	<.001[b]
	Residual	28832.583	18	1601.810		
	Total	821496492.550	19			

a. Dependent Variable: Cycles (Rendered)

b. Predictors: (Constant), Duration of movie clip

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	116.810	11.559		10.105	<.001
	Duration of movie clip	80.546	.112	1.000	716.126	<.001

a. Dependent Variable: Cycles (Rendered)

Figure 43: Regression Data (Blender file with 50 collections) Ubuntu VirtualBox: Model Summary; New Model with Regression, Residue and Total; Coefficients (Non-standardized and Standardized) - Cycles (Rendered).

As we can see, the viewport rendering on the Virtual Machine performed terribly, getting the worst results when comparing to the previous ones.

Like it was previously mentioned, Blender is a 3D computer graphics program that can make movies and render 2D/3D images.

3D Sculpting heavily depends on CPU and RAM, since most cases people are sculpting up several polygons, which could lead to performance degradation with a basic computer, and as a result, the frame rate will significantly drop.

As for Rendering, like we saw, there is a notorious difference when it comes to using Blender with a normal desktop/virtual machine and a gaming PC with a fast graphics card and a large memory. While it's not impossible, a normal desktop would take a very long time to render. There are some laptops that can struggle with heavy sustained workloads, and while it's not necessary to get a high-powered laptop to run Blender, its hardware will affect its performance. When it comes to gaming PC's, it's guaranteed that they will have High-powered GPU's and CPU's that can work well with Blender. There are many advantages of using a powerful computer, such as: less chances of crashing the program; scenes with large poly counts are more reactive; sculpt into much higher poly counts; reduces render times; real time rendering (eevee) can give instant feedback.

Although Blender can render very smoothly with multithreaded CPU, it can struggle on CPU's that mainly perform on single-core. There are several recommendation for the best CPUs for Blender, like the **AMD Threadripper 3970X**, the **AMD Ryzen 9 5900X**, and the **Intel i9 11900K**, although, while it has fast active work performance, it lacks multi-core performance.

When it comes to the GPU, Blender renders faster and smoother on CUDA, since it only works with Nvidia graphics cards, and Nvidia provides many resources. It also has Ray Tracing, which in here it's called OptiX. For CUDA, the recommendations for the best GPUs for Blender are, for performance **Nvidia RTX 3090**, and for low budget **Nvidia GTX 1660 Super**.

5 Conclusion

Key points:

- The explanation of the development of the animated movie allows the possibilities to make a film from the screenplay;
- To show the concept behind the generalized screenplay;
- To inspire film makers to be creative and to visualize their own movie;
- The recent results from this project could show some usefulness to the movie industry, gaming industry, psychiatry and psychology.

5.1 Development of a film straight from a screenplay

With the development of the OmegaSpec, Scriptsheet and MovieBirth tools, it's now possible to create low-cost animation movies straight from the screenplay that doesn't require many resources, in a way these tools can be used by people who are new to writing stories and the animation industry.

In order to develop the "Peace Wars" movie from its script, after reading the screenplay carefully and done some editing on the template, the OmegaSpec tool was then able to generalize the original script with some modifications (Headings, Descriptions, Characters, Transitions). These elements are the primary tools for the making of the movie.

Blender, like it was previously mentioned, is a free open-source 3D computer graphics software that is user friendly to newcomers. By learning the different tools and workspace it offered, we were able to make/import 3D models to create the environments from scratch. Nethertheless, Blender has its limitations, and although it is recommended to start with a few models for the rendering, it's important for movie makers to be creative when making the world, for instance the detail on the clothing, the animation, and the lighting.

When making the different collections for the scenes and the characters, the difficult step was animating the movement of the character, and while some of them were used from Mixamo, others were made from scratch. They needed simple names so that it would be easier to access them from the library, and that is where the idea of characters having an ID in the screenplay emerged from. Another problem was the timing of each scene. In the early stages we rendered the same scene by trial and error and checked which one was best suited, not only that, but we needed to check the position for each action within the Blender Timeline, to see if it would make with the dialogue. Luckily, with the help of Python's Text-to-Speech from Scriptsheet, we are now able to count the number of seconds for each scene and the action/dialogue for each character.

5.2 Concept of a generalized screenplay

During the 1900's (the silent era), screenplays were generally a synopsis of a film, and shortly after films grew in length and complexity. In the modern age, there are of course several ways to turn screenplays into movies. For starters, it's important to write a good script and to impress a producer or a director, one way to improve your writing is to have other people read it like co-workers or professionals as they can give advises to guide you in these early stages, so in other words it's important to get feedback but to also acknowledge criticism; read several and different screenplays to understand the writers' philosophy on storytelling; finding the type of audience you're aiming at; finding an agent or a manager can be useful as they can help screenwriters to sell their plays to film studios; meeting producers and directors is crucial, but the most important thing is to pitch the screenplay and to negotiate the terms of the agreement.

When it comes to writing screenplay for animation, some people consider to try becoming animators themselves, as this could improve their skills on computer graphics and animation and potentially turn this into a career, and search work or internships for the people who are new to the animation industry. However there are other options for writers who want to write in animation but don't want to become animators. When comparing animation screenplays and live-action screenplays, there is no difference in the formats as they still use the same elements like the scene heading and description, character names and their dialogue, however one key difference is that there is no limitation when writing an animation script, since writers can picture locations that are unrealistic or difficult to get there, creating complex character designs and building worlds through imagination.

As screenwriters create the characters, the world and the flow of the narrative, it's useful to separate each element to help distinguish what is what. If writers make scripts for shows or short films, it's not difficult to distinguish the different elements from the screenplay format, however if someone is determined to write a long and complex script, for instance a play with 300 pages and countless characters, the OmegaSpec is user friendly and will make the writer's life easier. Before starting with OmegaSpec, the writer must first think of the script as the blueprint for a movie, TV show or a video game, as it will determine the rules along its making, the elements and the format of the script. It's advisable for beginners to start on a small but reasonable script to help determine its run time, the scheduling and the budget. With the script finished the writer can now use OmegaSpec and Scriptsheet.

In the case of the screenplay used for this project, "Peace Wars", the concept behind these 2 tools was to create a program that could read the script and ask for different elements of the format and store them on a database. While reading the script, we learned more about its template, so the first and important step was to not only search all the major elements, but their positioning on the page, and by doing so it gave an idea on how to implement the rules for the OmegaSpec tool. The Scene Headings would indicate where the action was happening and it normally consisted of a location and a time, so it would establish if the scene takes place inside or outside and the time of day, and in this case the headings must be in capital letters; the Action lines simply tell the reader what they'll see and hear besides the dialogue; the Character indicates when it speaks and the dialogue is what the character says; the Transitions indicate the switch between two scenes. In OmegaSpec, while there are obvious differences in the screenplay elements like the position of the text, instead of the default black text, the viewer can now see the text with different colors to easily separate the elements and to add additional information. So for instance, with the finished generalized script, the headings now indicate which scene takes place, the character cues have the letter S, standing for scene, plus its respective number, this will of course tell when a character shows up and to help differentiate potential alterations throughout the movie like their appearances, and their ID which is used for MovieBirth and the sound tool that wasn't part of this project.

With the generalized script finished, next we had the important step for the transition between the screenplay and the movie, and that is the Scriptsheet. Although its main function is to store data of the elements of the script, the program needed to know the full length of the screenplay so that we could have an overall idea of the run time of the film, hence why the Text-to-Speech tool was used to simulate the run time of the script. Not only that, but we needed to know the time frames of each scene, the time of day, and the dialogue/animation for the characters, and while the user doesn't necessarily needs these timestamps to develop the movie, they'll be extremely beneficial and will save additional time. While making the characters and the environment in Blender, we needed a way to know the exact duration of the scenes and by extension the characters, so that, in view, when there is a scene transition, the previous scene would disappear, and to know the exact time when a character is animated, like raising their hands. With the timestamps created, we were able to do what was said previously, and with the IDs created in the generalized script, we were able to put a name for each animation for a certain character's skeleton/armature, and how long the animation lasts. Of course it's important to note that the timestamps aren't completely accurate, as some scenes had moments with no dialogue or action and nothing substantial happened, resulting in some cuts of the film and shortening its length.

Finally, with these 2 concepts thought in mind and created, we were able to focus on the development of the MovieBirth program and the animated movie.

5.3 The possibility to visualize a movie

With the many possibilities that the generalized script offers, screenwriters can now use not only OmegaSpec, but MovieBirth to visualize their movie and open many creative ways for its development. However, it's important to note that people, at the end of the day, need to practice on their writing, no matter how creative they are.

When writing a script, it's not just simply writing "an empty space on the desert" or "slowly zooming in the camera", as this is not what visual writing is about. There is a difference between writing while visualizing the movie and directing on paper. It's important to evoke and play with every scene, and while words are the main tools, writers shouldn't take everything literally as they should think of new ways of how to improve the scenery, how the actors should act in a specific moment and to find a middle ground to go beyond the limits of someone's imagination and to connect with the audience to understand and appreciate their piece of work. Of course most screenwriters and authors aren't directors and never visually interpreted their own material to the cinema. It's from experiences and trial and error that writers need to visualize a "map" that will help translate their story. When someone has a vision, they need to embrace it and explain filmmakers how they see the story, otherwise there could be some elements in the movie that writers aren't pleased to see, like how characters feel strange or the pacing of the movie. So instead of writing boring exposition, like walking down the street, screenwriters should go for a more visual vocabulary, like a child broke its neighbours window because he was playing football with his friends.

In regards to the format of the screenplay, the Scene Descriptions can be very difficult to write, but they are important steps to follow, if writers want to achieve good storytelling. It allows readers to experience the story as it unravels and gives them a taste how the movie could look on the big screen. The format of the text can be used in several ways, for instance text in capital letters could add significance to the scene, or adding simply one word could change tone of the scene; the actions of the characters and their motivations could give the reader a sense of their determination. As writers imagine the descriptions for each scene, in a way, they explore new points that can help stimulate the visualization process.

5.4 The usefulness of the developed tools

There are a different number of techniques that have been used to complement the fMRI study. One approach is to model the human brain as a network for every region, which could provide an foundation to study how the dynamic changes are connected to the brain structure and its states. Another way is the combination of fMRI with the electrophysiological response of the brain, by using magnetoencephalography (MEG) or electroencephalography (EEG), where both methods improve the temporal resolution of fMRI.

For the standard fMRI study, the results should contain information such as the peak cluster coordinates, the cluster's size, the brain regions that contain a reference, the statistical score, the comparisons correction, and so on. The fMRI results are never straightforward and depends upon certain factors, and because there is a big difference in the way with which studies are executed, clinics and researchers need to fully explain the results, as well as its details.

Coming up with significant answers about mental conditions from fMRI data can be quite challenging, luckily, the use of classification and machine learning algorithms have increasingly been more trusted in this area. Some conclusions are based on the assumption that when a region of activation changes as a task to perform a specific thing, the region that has changed is responsible for the related cognitive process. However, this assumption fails due to not taking into account the brain compensatory mechanisms, and when asking for a more suited description of brain function, it must be recognized the relation between interconnected regions.

Some studies seem to locate high degrees of correlation between the characteristics of human behaviours and certain region of brain activity. Some researchers have pointed out the circular analysis in functional studies, since when the fMRI data is analysed and the subsets are analysed again to get the results.

The movie fMRI, currently, presents some limitations that are left to be innovated. Unlike tasks, films are absent of built-in rates of task performance, though they could easily be fixed with in-scanner eye-tracking devices and intersubject associations of BOLD-signal time courses in the frontal eye field.

Although traditional resting state investigation can be imported to movie-view data, these solutions will likely miss movie-related signal changes. One type of analysis referred to as Intersubject functional connectivity (ISFC) depends on stimulus-locked dynamics to discover connectivity patterns. While test-retest reliability data looks promising so far, researchers still need to test reliability of measures that are gathered during different films and different types of audience.

In order to accelerate the progression of movie fMRI for psychiatry and the biomarkers, there are many ways. The Healthy Brain Network is an example of psychiatrically-centered imaging resource that has increased the popularity of movies fMRI+EEG. From a certain database, it marks several manuscripts by different parties, and while it mainly focuses on healthy adults, the movie fMRI is included on a subdivision of people. By using a deducible information about the arrangement of the human brain, we can obtain a better quality to-sample ratio, through the use of meta-analytically networks to indicate and focus on the location of a certain functional system in the course of the film stimulation. This could make use of the resting-state data, where it provides the way of understanding the human brain during certain conditions, which could lead to diagnostic tools that, through machine-learning, create large film database from each subject. To identify the ideal asset for biomarker research using films, some suggest the making and compiling a library for fMRI research to develop a list of conditions for movies like symptoms and/or disorder, and by starting with a common film paradigm could provide the key to find a reliable brain shape.

To support the future of fMRI and to overcome the usual challenges when performing fMRI studies, there are several strategies that can offer some usefulness for these types of problems. Prior to the research, people should perform a better planning, with a proper design and to identify specific targets, during the research, define the specific protocols and prevent potential problems, such as losing data, to analyse and to test the information that was gathered, and finally, report all the results with significant detail.

In short, movie fMRI is being recognized as a useful tool in psychiatry, and there are some guidelines that researchers can use to accelerate its progress, such as the making of large scale movie databases, choosing regions and networks from the brain based on certain characteristics present in the movies, and the use of film paradigms.

6 Future work

Key points:

- To reach a goal of changing the movie industry with independent film makers being able to produce their own movie with these developed tools;
- To find new ways to improve OmegaSpec, Scriptsheet and MoveBirth based on the results obtained in this project;
- To search for new ways to obtain better quality when it comes to the time for the viewport rendering;
- To create concepts for the making of a audio design software and the 3D Modeling software.

6.1 The future of individual movie making

One way to develop independent movies include the ability to modify its content. However, some drawbacks of independent movie-making is that there is no guarantee that these movies will be successful. Fortunately, the cost and the time that is required to develop these movies for neuroscience can guarantee a broad sharing of these stimuli, and these movie properties can be served as a medium for the sharing of movie-based paradigms.

In the modern age, most films have a structure, the most popular and widely utilized is the three-act structure. As the name suggests, a movie with a three-act structure has the following pattern: setup, confrontation, resolution. Throughout the acts, the screenwriter/filmmaker can break them down into scenes that include dialogue which in turn, helps to move the story forward. Understanding this structure is very important, as it provides the story's foundation and keeps it in balance. For example, movies like Avatar, Matrix and Star Wars have the three act structure. The first act of any story (setup), is the most important, being, of course, the opening of the story and tells the audience what they need to see. It sets up the characters (protagonists, antagonists, others) and the world around them. The second act (confrontation) can be divided into two parts, where the first part starts with the protagonist's reacting to what has happened so far, while the second part shows the characters having a conflict. The audience is now fully invested in the story, the protagonist's goals and what's at stake, where usually there could be a point of no return, where characters are presented with a choice. The third act (resolution) features the climax of the film, where the protagonists are forced to make decisions that will either help or hurt their chances of achieving their goals. This act is sometimes the most difficult act to write/execute, in the hopes it can satisfy the audience.

Regarding to the prediction of a movie's success, a movie that makes a large gross doesn't necessarily mean that it's "profitable". One important rule to qualify the movie is to compare the profits that was made to its budget, so in other words, if the movie has gained more than its budget, it's a success, otherwise if it's bellow then it's a flop. One important feature that filmmakers should consider is the genre, being a crucial factor for the people who attended the movie, where in today's world, the most popular genres are Comedy and Action.

While this topic focuses on individual movie making, when developing a movie on a huge scale, besides the filmmaker, there are other members who are just as important. A producer is the person who makes the movie happen. Although the director can both produce and direct, a producer focuses on the profits of the movie while the director focuses on the movie itself. The producer is also responsible to manage the current resources, to find actors, to complete the project in time, and to promote the movie to the target audience. The actors also have a difficult job, since they have to get their lines right while acting like a normal person in any circumstances, even pretending they're in a real life situation while performing on the set.

6.2 Improvements of the developed tools

Although these tools have showed great results, there's still some work that can be done to improve their quality.

For OmegaSpec, there will be 3 new additional elements to the coding: **Fade In/Out**; **Extensions**; **Parentheticals**; **Chyrons**. Like the other elements that were implemented, OmegaSpec will search these specific words/regular expressions and replace the standard black font for another color to stand out. Fade In/Out represent the beginning and the end of the screenplay, meaning that by adding the number of the scene, it will be **SCENE 1 - FADE IN; SCENE N - FADE OUT**, and its font color will be different from the Scene Heading (Red), Extensions are next to a character's name in parentheses and usually tell how the dialogue is heard by the audience, such as **CONTINUED (CONT'D)** to indicate their continuation of their dialogue after they're interrupted, **VOICE OVER (V.O.)** to show a character speaking over the action but isn't heard by any character in the scene, **OFF SCREEN (O.S.)** and **OFF CAMERA (O.C.)** where a character speaks but the audiance can't see; Parentheticals are essentially technical directions to the actor, in other words, they detail how he line should be performed; Chyrons or Title represent the text that usually indicates the time and place of the scene. There will be also an option for people who are color blind, which will add an symbol next to the text or to change the style of the text. Futhermore, once these steps are finished, we'll make desktop and mobile apps so that every writer can have access to the OmegaSpec tool.

For Scriptsheet, there will be new tables added to the database that will contain the data for all the audio/character's dialogue in the screenplay, their extension and parentheticals, their names and descriptions, which will be used for a sound making tool. Additionally, besides Excel, there will the other database management software options that users can choose, such as Microsoft SQL Server, MongoDB and many others. Much like OmegaSpec, we'll develop concepts for a potential desktop and mobile apps.

For both OmegaSpec and Scriptsheet, we'll add a speech recognition which will support several engines and APIs. With this library, users will then be able to search words and create documents by simply converting the words spoken into readable text. For the early stages, this library will only be implemented on the desktop version.

Finally, for MovieBirth, the Animation, Camera, Sound and Text tools will be updated, and latter the addon will be added to the Blender Market. Once that step is finished, the MovieBirth tool could be converted to other 3D modeling software that include python scripting, such as Autodesk Maya, Autodesk 3Ds Max, and Cinema 4D.

6.3 Processing-speed improvements

In order to obtain better results, the Blender software will need to be tested on other computers/virtual machines that have powerful hardware, CPU's and GPU's, such as Gaming Laptops, in order to increase its performance.

There are, of course, several tips that users can do to not only reduce the rendering time, but to also have the best quality. As it was mentioned before, Blender has 2 render engines: Eevee which is a physics-based renderer that performs in real-time; Cycles which is a physically-based ray-tracing renderer. There are also plugins that could install other engines. With Cycles being the most invested engine in Blender, and being a GPU-based engine, is much faster than the CPU.

It's preferable to have an Nvidia graphics card, since by enabling GPU rendering in the settings, the user can choose between CUDA or Optix, or HIP if the computer has an AMD graphics card. The type of graphic card is important, since while current GPU's can handle a huge number of objects, it can significantly speed up the process of rendering, but will have some memory limitations depending on the complexity of the scene.

While the engine aims for realism, it requires a longer rendering time, as for example, light paths can slow down the time. Luckily, this problem can be fixed in the Rendering Properties panel by reducing Blender's Max Bounces.

Optimizing the multiple importance sampling is beneficial, as dealing with environments that are high-resolution can cause Blender to freeze the program, especially due to the amount of time it takes to develop an importance map to have better results. This problem can be fixed by going to the settings, changing the sampling from auto to manual, and adjust the map resolution value.

When rendering a scene, the engine calculates the number of samplings, meaning the higher the samples count, the rendering result will be more accurate and cleaner. However, it will require more time. It's important to note that, while rendering a scene, there could be some samples that are unnecessary and even pointless to have, hence why users should do several test with different sampling to see if the results are the same, which could save some time.

Lastly for the Viewport Rendering, the Cycles Engine will centre all of the available assets to the region, and not the entire viewport, and since it's smaller, the engine will be able to get the results much faster. To choose a region to render, the user simply clicks Ctrl+B to pull out a box over the mesh.

6.4 Development of sound making tools and 3D Model/Animation tools

Although the tools that were developed mainly focused on editing screenplays and the making of animated films, one of the main objectives that will be implemented in the future is the making of a sound editing tool and a 3D computer graphics software.

In this project, while the developed tools utilize python scripts, the audio and the dialogue for the characters were created by a third party, and they were manually made by using online software tools.

The purpose of making a sound sound design software is to create voices for the characters in the screenplay, based on their description/biography (age, gender, behaviour), the extensions (VOICE OVER, OFF CAMERA), and the parentheticals (laughing, whispering, crying). With the help from Scriptsheet, the user will be able to insert all the information of the characters saved in the database. The sound tool will also include the option to import sound files and save them in the library so that they can used in the movie.

First, the tool will have a Digital Audio Workstation (DAW), as this will serve an hub which allows users to add multiple tracks of audio and even implement virtual instruments, and everything will come together to create the final product.

Next, its important to have an audio editor, since they work with a stereo audio file instead of a mix of audio files within the project. They can also offer tools that aren't available in DAW, for instance, the audio restoration, destructive editing, and the time and pitch stretching.

The sound tool will aim to include plugin, since they can offer very unique options to mix/create new sounds.

Blender was the main tool used for the modeling of the characters and the development of the film. However, besides the development of the sound tool, another objective to aim would be on the development of a small but simple 3D computer graphics software. The purpose of this would be to create 3D characters, in which the software would provide a library of 3D object and animations, such as wardrobes, poses, hairstyles, backgrounds, and even rendering tools. Similar to **Daz Studio**, it would support the import and export of various formats of characters and other 3D objects.

Bibliography

V. Anand. A study of time management: The correlation between video game usage and academic performance markers. *CyberPsychology & Behavior*, 10(4):552–559, 2007. doi: 10.1089/cpb.2007.9991.

C. Anderson and B. Bushman. Effects of violent video games on aggressive behavior, aggressive cognition, aggressive affect, physiological arousal, and prosocial behavior: a meta-analytic review of the scientific literature. *Psychol Sci.*, 12(5):353–359, 2001. doi: 10.1111/1467-9280.00366.

C. Anderson, A. Shibuya, N. Ihori, E. Swing, B. Bushman, A. Sakamoto, H. Rothstein, and M. Saleem. Violent video game effects on aggression, empathy, and prosocial behavior in eastern and western countries: a meta-analytic review. *Psychol Bull.*, 136(2):151–173, 2010. doi: 10.1037/a0018251.

L. Annetta, E. Etopio, J. Firestone, and R. Lamb. A meta-analysis with examination of moderators of student cognition, affect, and learning outcomes while using serious educational games, serious games, and simulations. *Computers in Human Behavior*, 80:158–167, 2018. doi: 10.1016/j.chb.2017.10.040.

B. Ashinoff. The potential of video games as a pedagogical tool. *Front Psychol.*, 5:1109, 2014. doi: 10.3389/fpsyg.2014.01109.

S. Atlas, R. Howard 2nd, J. Maldjian, D. Alsop, J. Detre, J. Listerud, M. D'Esposito, K. Judy, E. Zager, and M. Stecker. Functional magnetic resonance imaging of regional brain activity in patients with intracerebral gliomas: findings and implications for clinical management. *Neurosurgery*, 38(2):329–338, 1996. doi: 10.1097/00006123-199602000-00019.

J. Baccus, M. Baldwin, and D. Packer. Increasing implicit self-esteem through classical conditioning. *Psychol Sci.*, 15(7):498–502, 2004. doi: 10.1111/j.0956-7976.2004.00708.x.

P. Bandettini, E. Wong, R. Hinks, R. Tikofsky, and J. Hyde. Time course epi of human brain function during task activation. *Magn. Reson. Med.*, 25(2):390–397, 1992. doi: 10.1002/mrm.1910250220.

L. Bartholomew, R. Gold, G. Parcel, D. Czyzewski, M. Sockrider, M. Fernandez, R. Shegog, and P. Swank. Watch, discover, think, and act: Evaluation of computer-assisted instruction to improve asthma self-management in inner-city children. *Patient Educ Couns.*, 39(2-3):269–280, 2000. doi: 10.1016/s0738-3991(99)00046-4.

C. Bateman. Meet bertie the brain, the world's first arcade game, built in toronto. 2014.

B. Bediou, D. Adams, R. Mayer, E. Tipton, C. Green, and D. Bavelier. Meta-analysis of action video game impact on perceptual, attentional, and cognitive skills. *Psychol Bull.*, 144(1):77–110, 2018. doi: 10.1037/bul0000130.

B. Biswal, F. Yetkin, V. Haughton, and J. Hyde. Functional connectivity in the motor cortex of resting human brain using echo-planar mri. *Magn. Reson. Med.*, 34(4):537–541, 1995. doi: 10.1002/mrm.1910340409.

A. Bizzi, V. Blasi, A. Falini, P. Ferroli, M. Cadioli, U. Danesi, D. Aquino, C. Marras, D. Caldiroli, and G. Broggi. Presurgical functional mr imaging of language and motor functions: validation with intraoperative electrocortical mapping. *Radiology*, 248(2):579–589, 2008. doi: 10.1148/radiol.2482071214.

A. Blamire, S. Ogawa, K. Ugurbil, D. Rothman, G. McCarthy, J. Ellermann, F. Hyder, Z. Rattner, and R. Shulman. Dynamic mapping of the human visual cortex by high-speed magnetic resonance imaging. *Proc. Natl. Acad. Sci. U.S.A.*, 89(22):11069–11073, 1992. doi: 10.1073/pnas.89.22.11069.

S. Brown, D. Lieberman, B. Gemeny, Y. Fan, D. Wilson, and D. Pasta. Educational video game for juvenile diabetes: Results of a controlled trial. *Medical Informatics*, 22(1):77––89, 1997. doi: 10.3109/14639239709089835.

C. Cath, S. Wachter, B. Mittelstadt, M. Taddeo, and L. Floridi. Artificial intelligence and the 'good society': The us, eu, and uk approach. *Sci Eng Ethics*, 24(2):505–528, 2018. doi: 10.1007/s11948-017-9901-7.

G. Chartrand, P. Cheng, E. Vorontsov, M. Drozdzal, S. Turcotte, C. Pal, S. Kadoury, and A. Tang. Deep learning: A primer for radiologists. *Radiographics*, 37(7):2113–2131, 2017. doi: 10.1148/rg.2017170077.

X. Chen. The relationship between video games, problem-solving skills, and academic performance from it students' perspective. 2019.

S. Chiu, J. Lee, and D. Huang. Video game addiction in children and teenagers in taiwan. *Cyberpsychol. Behav.*, 7 (5):571–581, 2004. doi: 10.1089/cpb.2004.7.571.

M. Cohn, B. Fredrickson, S. Brown, J. Mikels, and A. Conway. Happiness unpacked: positive emotions increase life satisfaction by building resilience. *Emotion*, 9(3):361–368, 2009. doi: 10.1037/a0015952.

R. Cox, A. Jesmanowicz, and J. Hyde. Real-time functional magnetic resonance imaging. *Magn. Reson. Med.*, 33 (2):230–236, 1995. doi: 10.1002/mrm.1910330213.

M. Csikszentmihalyi. *Flow: the psychology of happiness*. Ebury Publishing, 2013.

J. Damoiseaux, S. Rombouts, F. Barkhof, P. Scheltens, C. Stam, S. Smith, and C. Beckmann. Consistent resting-state networks across healthy subjects. *Proc. Natl. Acad. Sci. U.S.A.*, 103(37):13848–13853, 2006. doi: 10.1073/pnas.0601417103.

T. Dang. Ai transforming the world. 2019. URL https://www.forbes.com/sites/cognitiveworld/2019/02/24/ai-transforming-the-world/?sh=5508015d4f03.

J. Daniel. Education and the covid-19 pandemic. *Prospects (Paris)*, 49(1-2):91–96, 2020. doi: 10.1007/s11125-020-09464-3.

D. Das, K. Grimmer, A. Sparnon, S. McRae, and B. Thomas. The efficacy of playing a virtual reality game in modulating pain for children with acute burn injuries: a randomized controlled trial [isrctn87413556]. *BMC Pediatr.*, 5(1):1, 2005. doi: 10.1186/1471-2431-5-1.

S. David, W. Vinje, and J. Gallant. Natural stimulus statistics alter the receptive field structure of v1 neurons. *J. Neurosci.*, 24(31):6991–7006, 2004. doi: 10.1523/JNEUROSCI.1422-04.2004.

S. Eickhoff, M. Milham, and T. Vanderwal. Towards clinical applications of movie fmri. *NeuroImage*, 217:116860, 2020. doi: 10.1016/j.neuroimage.2020.116860.

W. Elsayed. The negative effects of social media on the social identity of adolescents from the perspective of social work. *Heliyon*, 7(2):e06327, 2021. doi: 10.1016/j.heliyon.2021.e06327.

C. Engelhardt, B. Bartholow, G. Kerr, and B. Bushman. This is your brain on violent video games: neural desensitization to violence predicts increased aggression following violent video game exposure. *J Exp Soc Psychol.*, 47(5):1033––1036, 2011. doi: 10.1016/j.jesp.2011.03.027.

A. Estévez, P. Jáuregui, I. Sánchez-Marcos, H. López-González, and M. Griffiths. Attachment and emotion regulation in substance addictions and behavioral addictions. *J. Behav. Addict.*, 6(4):534–544, 2017. doi: 10.1556/2006.6.2017.086.

S. Feldstein. The global expansion of ai surveillance. 2019.

M. Fox and M. Raichle. Spontaneous fluctuations in brain activity observed with functional magnetic resonance imaging. *Nat. Rev. Neurosci.*, 8(9):700–711, 2007. doi: 10.1038/nrn2201.

B. Fredrickson and T. Joiner. Positive emotions trigger upward spirals toward emotional well-being. *Psychol Sci.*, 13(2):172–175, 2002. doi: 10.1111/1467-9280.00431.

K. Friston, J. Kahan, A. Razi, K. Stephan, and S. O. On nodes and modes in resting state fmri. *Neuroimage*, 99: 533–547, 2014. doi: 10.1016/j.neuroimage.2014.05.056.

D. Gentile. Pathological video-game use among youth ages 8 to 18: a national study. *Psychol. Sci.*, 20(5):594–602, 2009. doi: 10.1111/j.1467-9280.2009.02340.x.

D. Gentile, P. Lynch, J. Linder, and D. Walsh. The effects of violent video game habits on adolescent hostility, aggressive behaviors, and school performance. *Journal of Adolescence*, 27(1):5–22, 2004. doi: 10.1016/j.adolescence.2003.10.002.

C. Gloria and M. Steinhardt. Relationships among positive emotions, coping, resilience and mental health. *Stress Health*, 32(2):145–156, 2016. doi: 10.1002/smi.258.

B. Goertzel. Artificial general intelligence: Concept, state of the art, and future prospects. *J. Artif. Gen. Intell.*, 5: 1-–48, 2014. doi: 10.2478/jagi-2014-0001.

J. Gold, S. Kim, A. Kant, M. Joseph, and A. Rizzo. Effectiveness of virtual reality for pediatric pain distraction during i.v. placement. *Cyberpsychol Behav.*, 9(2):207-–212, 2006. doi: 10.1089/cpb.2006.9.207.

M. Graetz. The origin of spacewar. *Creative Computing*, 6(8):56–67, 1981. ISSN 0097-8140.

C. Green and D. Bavelier. Action video game training for cognitive enhancement. *Curr Opin Behav Sci.*, 4:103–108, 2015. doi: 10.1016/j.cobeha.2015.04.012.

B. Greenberg, J. Sherry, K. Lachlan, K. Lucas, and A. Holmstrom. Orientations to video games among gender and age groups. *Simul. Gaming*, 41:238–259, 2010. doi: 10.1177/1046878108319930.

G. Greene. The art and legacy of the '90s console war, 2015. URL https://venturebeat.com/business/the-art-and-legacy-of-the-90s-console-war/.

E. Greenglass and L. Fiksenbaum. Proactive coping, positive affect, and well-being. *Eur Psychol.*, 14(1):29–39, 2009. doi: 10.1027/1016-9040.14.1.29.

M. Griffiths. The educational benefits of videogames. *Education and Health*, 20(3):47–51, 2002.

M. Griffiths. Video games and health. *BMJ*, 331(7509):122-–123, 2005. doi: 10.1136/bmj.331.7509.122.

T. Grodal. *Embodied Visions: Evolution, Emotion, Culture and Film.* 2009. ISBN 978-0195371321.

H. Guan, A. Okely, N. Aguilar-Farias, C. del Pozo Cruz, B.and Draper, A. El Hamdouchi, A. Florindo, A. Jáuregui, P. Katzmarzyk, A. Kontsevaya, M. Löf, W. Park, J. Reilly, D. Sharma, M. Mark S Mark S Tremblay, and S. Veldman. Promoting healthy movement behaviours among children during the covid-19 pandemic. *Lancet Child Adolesc. Health*, 4(6):416–418, 2020. doi: 10.1016/S2352-4642(20)30131-0.

W. Hall, P. Kim, and C. Truwit. Functional magnetic resonance imaging-guided brain tumor resection. *Top Magn Reson Imaging.*, 19(4):205–212, 2009. doi: 0.1097/RMR.0b013e3181934a09.

K. Haninger and K. Thompson. Content and ratings of teen-rated video games. *JAMA*, 291(7):856–865, 2004. doi: 10.1001/jama.291.7.856.

U. Hasson, Y. Nir, I. Levy, G. Fuhrmann, and R. Malach. Intersubject synchronization of cortical activity during natural vision. *Science*, 303(5664):1634–1640, 2004. doi: 10.1126/science.1089506.

U. Hasson, R. Malach, and D. Heeger. Reliability of cortical activity during natural stimulation. *Trends Cognit. Sci.*, 14(1):40–48, 2010. doi: 10.1016/j.tics.2009.10.011.

A. Heller, L. Greischar, A. Honor, M. Anderle, and R. Davidson. Simultaneous acquisition of corrugator electromyography and functional magnetic resonance imaging: a new method for objectively measuring affect and neural activity concurrently. *Neuroimage*, 58(3):930–934, 2011. doi: 10.1016/j.neuroimage.2011.06.057.

K. Hewett, G. Zeng, and B. Pletcher. The acquisition of 21st-century skills through video games: Minecraft design process models and their web of class roles. *Simulat Gaming*, 51(3):336–364, 2020. doi: 10.1177/1046878120904976.

M. Hollmann, J. Rieger, S. Baecke, R. Lützkendorf, C. Müller, D. Adolf, and J. Bernarding. Predicting decisions in human social interactions using real-time fmri and pattern classification. *PLoS One*, 6(10):e25304, 2011. doi: 10.1371/journal.pone.0025304.

D. Jakhar and I. Kaur. Artificial intelligence, machine learning and deep learning: Definitions and differences. *Clin Exp Dermatol.*, 45(1):131–132, 2020. doi: 10.1111/ced.14029.

J. Javad, 2020. https://www.wfaa.com/ and https://www.wfaa.com/article/sports/esports-gaming-industry-thriving-as-video-games-provide-escape-from-reality-during-coronavirus-pandemic/287-5953d982-d240-4e2b-a2ba-94dd60a8a383.

E. Jeong and D. Kim. Social activities, self-efficacy, game attitudes, and game addiction. *Cyberpsychol. Behav. Soc. Netw.*, 14(4):213–221, 2011. doi: 10.1089/cyber.2009.0289.

M. Jimenez De La Pena, S. Gil Robles, M. Recio Rodriguez, C. Ruiz Ocana, and V. Martinez De Vega. Cortical and subcortical mapping of language areas: correlation of functional mri and tractography in a 3t scanner with intraoperative cortical and subcortical stimulation in patients with brain tumors located in eloquent areas. *Radiologia*, 55(6):505–513, 2013. doi: 10.1016/j.rx.2012.01.004.

M. Kaipainen, N. Ravaja, P. Tikka, R. Vuori, R. Pugliese, M. Rapino, and T. Takala. Enactive systems and enactive media: embodied human - machine coupling beyond interfaces. *Leonardo*, 44(5):433–438, 2011. doi: 10.1162/LEON_a_00244.

I. Kapsalakis, E. Kapsalaki, E. D. Gotsis, D. Verganelakis, P. Toulas, G. Hadjigeorgiou, I. Chung, I. Fezoulidis, A. Papadimitriou, J. Robinson, G. Lee, and K. Fountas. Preoperative evaluation with fmri of patients with intracranial gliomas. *Radiol Res Pract.*, 2012:727810, 2012. doi: 10.1155/2012/727810.

G. Kasparov, M. Sadler, and N. Regan. Game changer: Alphazero's groundbreaking chess strategies and the promise of ia. page 10. 2019.

D. Kasteleijn-Nolst Trenite, A. Martins da Silva, S. Ricci, G. Rubboli, C. Tassinari, J. Lopes, M. Bettencourt, J. Oosting, and J. Segers. Video games are exciting: a european study of video game-induced seizures and epilepsy. *Epileptic Disord*, 4(2):121–128, 2002.

S. Kent. *The ultimate history of video games: from Pong to Pokémon and beyond : the story behind the craze that touched our lives and changed the world*. Prima, 2001. ISBN 0-7615-3643-4.

B. Kenwright. Siggraph asia 2017 symposium on education. page 1–10, 2017.

M. Klein. Google's alphazero destroys stockfish in 100-game match. 2017. URL https://www.chess.com/news/view/google-s-alphazero-destroys-stockfish-in-100-game-match;https://perma.cc/8WGK-HKYZ.

C. Ko, J. Yen, C. Chen, S. Chen, and C. Yen. Gender differences and related factors affecting online gaming addiction among taiwanese adolescents. *J. Nervous Mental Dis.*, 193(4):273–277, 2005. doi: 10.1097/01.nmd.0000158373.85150.57.

M. Koepp, R. Gunn, A. Lawrence, V. Cunningham, A. Dagher, T. Jones, D. Brooks, C. Bench, and P. Grasby. Evidence for striatal dopamine release during a video game. *Nature*, 393(6682):266–268, 1998. doi: 10.1038/30498.

V. Kumar, K. Wentzell, T. Mikkelsen, A. Pentland, and L. Laffel. The daily (daily automated intensive log for youth) trial: a wireless, portable system to improve adherence and glycemic control in youth with diabetes. *Diabetes Technol Ther.*, 6(4):445––453, 2004. doi: 10.1089/1520915041705893.

K. Kwong, J. Belliveau, D. Chesler, I. Goldberg, R. Weisskoff, B. Poncelet, D. Kennedy, B. Hoppel, M. Cohen, R. Turner, H.-M. Cheng, T. Brady, and B. Rosen. Dynamic magnetic resonance imaging of human brain activity during primary sensory stimulation. *Proc. Natl. Acad. Sci. U.S.A.*, 89(12):5675–5679, 1992. doi: 10.1073/pnas.89.12.5675.

S. LaConte. Decoding fmri brain states in real-time. *Neuroimage*, 56(2):440–454, 2011. doi: 10.1016/j.neuroimage.2010.06.052.

L. Lanningham-Foster, T. Jensen, R. Foster, A. Redmond, B. Walker, D. Heinz, and J. Levine. Energy expenditure of sedentary screen time compared with active screen time for children. *Pediatrics*, 118(6):e1831–e1835, 2006. doi: 10.1542/peds.2006-1087.

J. Lee, J. Kim, and S. Yoo. Real-time fmri-based neurofeedback reinforces causality of attention networks. *Neurosci. Res.*, 72(4):347–354, 2012. doi: 10.1016/j.neures.2012.01.002.

J. Lemmens, P. Valkenburg, and J. Peter. Psychosocial causes and consequences of pathological gaming. *Comput. Hum. Behav.*, 27:144–152, 2011. doi: 10.1016/j.chb.2010.07.015.

N. Lori, E. Samit, G. Picciochi, and P. Jesus. Free-will perception in human mental health: an axiomatic formalization. in: Automata's inner movie: Science and philosophy of mind. 2019.

X. Ma, H. Zhang, X. Zhao, L. Yao, and Z. Long. Semi-blind independent component analysis of fmri based on real-time fmri system. *IEEE Trans. Neural Rehabil. Eng.*, 21(3):416–426, 2012. doi: 10.1109/TNSRE.2012.2184303.

R. Mar and K. Oatley. The function of fiction is the abstraction and simulation of social experience. *Perspect. Psychol. Sci.*, 3(3):173––192, 2008. doi: 10.1111/j.1745-6924.2008.00073.x.

J. McCarthy. What is artificial intelligence? 2007.

J. McCarthy, M. Minsky, N. Rochester, and C. Shannon. A proposal for the dartmouth summer conference on artificial intelligence. 1995.

M. Mehroof and M. Griffiths. Online gaming addiction: the role of sensation seeking, self-control, neuroticism, aggression, state anxiety, and trait anxiety. *Cyberpsychol. Behav.*, 13(3):313––316, 2010. doi: 10.1089/cyber.2009.0229.

L. Milani, G. La Torre, M. Fiore, S. Grumi, D. Gentile, M. Ferrante, S. Miccoli, and P. Di Blasio. Internet gaming addiction in adolescence: risk factors and maladjustment correlates. *Int. J. Mental Health Addict.*, 16:888–904, 2018. doi: 10.1007/s11469-017-9750-2.

Y. Morabit, F. Mrabti, and E. Abarkan. Survey of artificial intelligence approaches in cognitive radio networks. *Journal of Information and Communication Convergence Engineering*, 17(1):21––40, 2019. doi: 10.6109/jicce.2019.17.1.21.

C. Morewedge. How a video game helped people make better decisions, 2015. URL https://hbr.org/2015/10/how-a-video-game-helped-people-make-better-decisions.

F. Morgan, B. Boudreaux, A. Lohn, M. Ashby, C. Curriden, K. Klima, and D. Grossman. *Military applications of artificial intelligence: Ethical concerns in an uncertain world*. Santa Monica, CA: RAND Corporation, 2020. ISBN 9781977404923. doi: 10.7249/RR3139-1.

N. Nilsson. Artificial intelligence: A new synthesis. 1998.

S. Ogawa and T. Lee. Magnetic resonance imaging of blood vessels at high fields: in vivo and in vitro measurements and image simulation. *Magn. Reson. Med.*, 16(1):9–18, 1990. doi: 10.1002/mrm.1910160103.

S. Ogawa, D. Tank, R. Menon, J. Ellermann, S. Kim, H. Merkle, and K. Ugurbil. Intrinsic signal changes accompanying sensory stimulation: functional brain mapping with magnetic resonance imaging. *Proc. Natl. Acad. Sci. U.S.A.*, 89(13):5951–5955, 1992. doi: 10.1073/pnas.89.13.5951.

T. Ota, K. Kamada, S. Aoki, and N. Saito. Visualization of calculation centres by functional mri for neurosurgery. *British journal of neurosurgery*, 23(4):406–411, 2009. doi: 10.1080/02688690902838815.

D. O'Connor, N. Potler, M. Kovacs, T. Xu, L. Ai, J. Pellman, T. Vanderwal, L. Parra, S. Cohen, S. Ghosh, J. Escalera, N. Grant-Villegas, Y. Osman, A. Bui, R. Craddock, and M. Milham. The healthy brain network serial scanning initiative: a resource for evaluating inter-individual differences and their reliabilities across scan conditions and sessions. *GigaScience*, 6(2):1–14, 2017. doi: 10.1093/gigascience/giw011.

C. Paquola, J. Seidlitz, O. Benkarim, J. Royer, P. Klimes, R. Bethlehem, S. Larivière, R. Vos de Wael, R. Rodríguez-Cruces, J. Hall, B. Frauscher, J. Smallwood, and B. Bernhardt. A multiscale cortical wiring space links cellular architecture and functional dynamics in the human brain. *PLoS Biol*, 18(11):e3000979, 2020. doi: 10.1371/journal.pbio.3000979.

Pete. Alphazero crushes stockfish in new 1,000-game match. 2019. URL https://www.chess.com/news/view/updated-alpha-zero-crushes-stockfish-in-new-1-000-game-match.

R. Pine, T. Fleming, S. McCallum, and K. Sutcliffe. The effects of casual videogames on anxiety, depression, stress, and low mood: a systematic review. *Games Health J.*, 9(4):255–264, 2020. doi: 10.1089/g4h.2019.0132.

H. Polman, B. de Castro, and M. van Aken. Experimental study of the differential effects of playing versus watching violent video games on children's aggressive behavior. *Aggress Behav.*, 34(3):256–264, 2008. doi: 10.1002/ab.20245.

J. Quoidbach, E. Berry, M. Hansenne, and M. Mikolajczak. Positive emotion regulation and well-being: comparing the impact of eight savoring and dampening strategies. *Personality Ind Diff.*, 49(5):368–373, 2010. doi: 10.1016/j.paid.2010.03.048.

K. Rankin, L. Walsh, and K. Sweeny. A better distraction: exploring the benefits of flow during uncertain waiting periods. *Emotion*, 19(5):818––828, 2019. doi: 10.1037/emo0000479.

N. Ravaja. Contributions of psychophysiology to media research: review and recommendations. *Media Psychol.*, 6(2):193–235, 2004. doi: 10.1207/s1532785xmep0602_4.

F. Rehbein, A. Staudt, M. Hanslmaier, and S. Kliem. Video game playing in the general adult population of germany: can higher gaming time of males be explained by gender specific genre preferences? *Comput. Hum. Behav.*, 55:729–735, 2016. doi: 10.1016/j.chb.2015.10.016.

E. Rikandi, S. Pamilo, T. Mäntylä, J. Suvisaari, T. Kieseppä, R. Hari, M. Seppä, and T. Raij. Precuneus functioning differentiates first-episode psychosis patients during the fantasy movie alice in wonderland. *Psychol. Med.*, 47(3):495–506, 2017. doi: 10.1017/S0033291716002609.

H. Roberts, J. Cowls, J. Morley, M. Taddeo, and V. Wang. The chinese approach to artificial intelligence: An analysis of policy, ethics, and regulation. *AI & SOCIETY*, 36:59–77, 2020. doi: 10.1007/s00146-020-00992-2.

B. Rosenberg, D. Landsittel, and T. Averch. Can video games be used to predict or improve laparoscopic skills? *J Endourol.*, 19(3):372–376, 2005. doi: 10.1089/end.2005.19.372.

J. Rosser, J.C., P. Lynch, L. Cuddihy, D. Gentile, J. Klonsky, and R. Merrell. The impact of video games on training surgeons in the 21st century. *Arch Surg.*, 142(2):181–186, 2007. doi: 10.1001/archsurg.142.2.181.

F. Roux, K. Boulanouar, J. Lotterie, M. Mejdoubi, J. LeSage, and I. Berry. Language functional magnetic resonance imaging in preoperative assessment of language areas: correlation with direct cortical stimulation. *Neurosurgery*, 52(6):1335–1345, 2003. doi: 10.1227/01.neu.0000064803.05077.40.

D. Rubin, J. Leventhal, and R. Sadock. Educational intervention by computer in childhood asthma: A randomized clinical trial testing the use of a new teaching intervention in childhood asthma. *Pediatrics*, 77(1):1––10, 1986.

S. Russell and J. Bohannon. Artificial intelligence. fears of an ai pioneer. *Science*, 349(6245):252, 2015. doi: 10.1126/science.349.6245.252.

C. Russoniello, K. O'Brien, and J. Parks. The effectiveness of casual video games in improving mood and decreasing stress. *J Cyber Ther. Rehab.*, 2(1):53––66, 2009.

J. Salmi, M. Metwaly, J. Tohka, K. Alho, S. Leppämäki, P. Tani, A. Koski, T. Vanderwal, and M. Laine. Adhd desynchronizes brain activity during watching a distracted multi-talker conversation. *NeuroImage*, 216:116352, 2020. doi: 10.1016/j.neuroimage.2019.116352.

M. Schölvinck, A. Maier, F. Ye, J. Duyn, and L. D.A. Neural basis of global resting-state fmri activity. *Proc. Natl. Acad. Sci. U.S.A.*, 107(22):10238–10243, 2010. doi: 10.1073/pnas.0913110107.

M. Seligman and M. Csikszentmihalyi. Positive psychology: an introduction. *Am Psychol.*, 55(1):5–14, 2000. doi: 10.1037/0003-066X.55.1.5.

F. Signorelli, J. Guyotat, J. Isnard, F. Schneider, R. Mohammedi, and P. Bret. The value of cortical stimulation applied to the surgery of malignant gliomas in language areas. *Neurol Sci.*, 22(1):3–10, 2001. doi: 0.1007/s100720170029.

F. Signorelli, J. Guyotat, F. Schneider, J. Isnard, and P. Bret. Technical refinements for validating functional mri-based neuronavigation data by electrical stimulation during cortical language mapping. *Minim Invasive Neurosurg.*, 46 (5):265–268, 2003. doi: 10.1055/s-2003-44454.

S. Sonkusare, M. Breakspear, and C. Guo. Naturalistic stimuli in neuroscience: critically acclaimed. *Trends Cognit. Sci.*, 23(8):699–714, 2019. doi: 10.1016/j.tics.2019.05.004.

H. Spiers and E. Maguire. Decoding human brain activity during real-world experiences. *Trends Cognit. Sci.*, 11(8): 356–365, 2007. doi: 10.1016/j.tics.2007.06.002.

E. Stanmore, B. Stubbs, D. Vancampfort, E. de Bruin, and J. Firth. The effect of active video games on cognitive functioning in clinical and non-clinical populations: A meta-analysis of randomized controlled trials. *Neurosci Biobehav Rev.*, 78:34–43, 2017. doi: 10.1016/j.neubiorev.2017.04.011. URL https://linkinghub.elsevier.com/retrieve/pii/S0149-7634(17)30129-X.

T. Stoffregen, E. Faugloire, K. Yoshida, M. Flanagan, and O. Merhi. Motion sickness and postural sway in console video games. *Hum Factors*, 50(2):322–331, 2008. doi: 10.1518/001872008X250755.

E. Tan. *Emotion and the Structure of the Narrative Film*. 1996.

K. Thompson and K. Haninger. Violence in e-rated video games. *JAMA*, 286(5):591–598, 2001. doi: 10.1001/jama.286.5.591.

P. Tikka. *Enactive Cinema: Simulatorium Eisensteinense*. Publication Series of the University of Art and Design Helsinki A 89, 2008. ISBN 978-952-60-3651-9.

P. Tikka, R. Vuori, and M. Kaipainen. Narrative logic of enactive cinema: 'obsession'. *Digital Creativity*, 17(4): 205–212, 2006. doi: 10.1080/14626260601074078.

J. Topolsky. Hello, google play: Google launches sweeping revamp of app, book, music, and video stores. 2012.

B. Tran, R. McIntyre, C. Latkin, H. Phan, G. Vu, H. Nguyen, K. Gwee, C. Ho, and R. Ho. The current research landscape on the artificial intelligence application in the management of depressive disorders: A bibliometric analysis. *Int J Environ Res Public Health*, 16(12):2150, 2019. doi: 10.3390/ijerph16122150.

A. Vallesi, S. Arbula, M. Capizzi, F. Causin, and D. D'Avella. Domain-independent neural underpinning of task-switching: an fmri investigation. *Cortex*, 65C:173–183, 2015. doi: 10.1016/j.cortex.2015.01.016.

D. Vilozni, M. Barker, H. Jellouschek, G. Heimann, and H. Blau. An interactive computer-animated system (spirogame) facilitates spirometry in preschool children. *Am J Respir Crit Care Med.*, 164(12):2200–2205, 2001. doi: 10.1164/ajrccm.164.12.2101002.

J. Voyvodic, G. Glover, D. Greve, and S. Gadde. Automated real-time behavioral and physiological data acquisition and display integrated with stimulus presentation for fmri. *Front. Neuroinform.*, 5:27, 2011. doi: 10.3389/fninf.2011.00027.

H. Wang, H. Cho, and D.-J. Kim. Prevalence and correlates of comorbid depression in a nonclinical online sample with dsm-5 internet gaming disorder. *J. Affect. Disord*, 226:1–5, 2018. doi: 10.1016/j.jad.2017.08.005.

D. Warburton, S. Bredin, L. Horita, D. Zbogar, J. Scott, B. Esch, and R. Rhodes. The health benefits of interactive video game exercise. applied physiology, nutrition, and metabolism. *Education and Health*, 32(4):655–663, 2007. doi: 10.1139/H07-038.

D. West and J. Allen. How artificial intelligence is transforming the world. 2018.

N. Wilkinson, R. Ang, and D. Goh. Online video game therapy for mental health concerns: a review. *Int J Soc Psychiatry*, 54(4):370––382, 2008. doi: 10.1177/0020764008091659.

M. Wilms, L. Schilbach, U. Pfeiffer, G. Bente, G. Fink, and K. Vogeley. It's in your eyes—using gaze-contingent stimuli to create truly interactive paradigms for social cognitive and affective neuroscience. *Soc. Cogn. Affect. Neurosci.*, 5(1):98–107, 2010. doi: 10.1093/scan/nsq024.

WIPO. *WIPO Technology Trends 2019: Artificial Intelligence*. Geneva: World Intellectual Property Organization, 2019. ISBN 9789280530070. doi: 10.34667/tind.29084.

B. Yawn, P. Algatt-Bergstrom, R. Yawn, P. Wollan, M. Greco, M. Gleason, and L. Markson. An in-school cd-rom asthma education program. *J Sch Health*, 70(4):153–159, 2000. doi: 10.1111/j.1746-1561.2000.tb06462.x.

A. Zapata, A. Moraes, C. Leone, U. Doria-Filho, and C. Silva. Pain and musculoskeletal pain syndromes related to computer and video game use in adolescents. *Eur J Pediatr.*, 165(6):408––414, 2006. doi: 10.1007/s00431-005-0018-7.