POLITECNICO DI TORINO

Master's Degree Course in Cinema and Media Engineering

Master's Thesis

Changes and Evolution in Audiovisual Production

The impact of digital and virtual technologies on standards and practices

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Abstract

Since the birth of Cinema, audiovisual production has been shaped by rigorous standards and processes: very well known books and studies about Movie and TV production have been released over the years, teaching the job divisions on sets, the organization of the projects in the pre, mid and post-production phases, costs and budget managing and more.
Today, the audiovisual industry faces radical changes due to the introduction of technologies that allow the production workflow to be less constrained by the old waterfall approach of old standards and to become more collaborative and agile. Virtual technologies, real-time rendering engines, and computer manipulation and simulation are the main tools leading this evolution.
The professionals involved in production are evolving along with the processes. Among the different formats, some general trends can be observed, such as a contamination of professional figures from the software and game development world, alongside a transformation of traditional expertise, which now tend to specialize more deeply in particular fields of their work.
Significant changes can also be observed in distribution practices: online streaming platforms are modifying the classical approach of movie distribution, while interactive and immersive works still struggle to be experienced by large audiences.
Last but not least, conservation, preservation, and accessibility of flat works benefit from digitalization: stable and distributed storage infrastructures can contain digital versions of audiovisual content, guaranteeing conservation safety and easy access via online platforms.
Meanwhile, works involving a good amount of coding and programming can benefit from the software and game development practice of creating design and code documentation.
This research analyzes the implications of these changes, comparing them to the old standards and practices of the audiovisual industry, and aims to theorize what the future of audiovisual productions will reserve us.
All the concepts and observations result from an investigation period at the National Film Board of Canada and subsequent analysis and elaboration through bibliographical resources.

Acknowledgements

Words cannot express my gratitude to Professor Tatiana Mazali and Eloi Champagne for giving me the opportunity to work on this project in such extraordinary conditions: learning and investigating inside the National Film Board of Canada has been an honor and a wonderful experience.

I am also grateful to all the NFB people who participated in this research project. Their knowledge and experience have inspired me, and I wish for my future to be able to do the same for someone else.

I would be remiss in not mentioning my family, especially my parents and my brother. Their support has kept my motivation high during this career.
Lastly, thanks to all my colleagues and friends from Cinema and Media Engineering, Residenza Borsellino, Robin Studio, and Turin, whose presence has always guaranteed me a smile.

Contents

Introduction

The history of audiovisual storytelling is long and intricate; since the early 1900's Cinema first and Television later have constantly been changing the way of telling stories, creating a new kind of audience.
The change did not only involve stories and spectators though: as a matter of fact, the production of those fresh-born media led to the creation of new kinds of jobs, investments, institutions, and companies. Cinema and Television production started to grow and, as a consequence, this growth brought with it standards that nowadays are well known and affirmed: books and courses about Movie and TV production have been released over the years, teaching the job divisions on sets, the organization of the projects in the pre, mid and post-production phases, costs and budget managing and more.
Everything appeared to be stable until the rise of new changes.
The end of the millennium carried new possibilities for audiovisual media leading to the need for a new grammar, new storytelling, new skills, and as an outcome the definition of new standards. Immersive storytelling, 3D animation, digital manipulation, and Virtual Reality are only a few of the possibilities that the new technology offers to content creators.

Having studied and worked during my university career with some of these new technologies, I started to ask myself several questions:
How has Cinema and Television production process changed during this revolution, and have new forms of production appeared? Can the classical job division and professional figures of traditional cinema manuals be efficient in new production workflows? Is the distribution of audiovisual products evolving?

This document aims to illustrate how the production process, the professionals, and the distribution practices of this field are changing due to the introduction of new technologies, through an analysis of the past and present state of the audiovisual industry.
Based on this information, an hypothesis is then formulated as to the direction these media might take in the future.

The Research

The entire thesis is based on a socio-technical research approach focusing on human, social, and organizational factors, as well as technical ones, connected to the production processes and practices in the audiovisual industry.
Most of the research process took place at the National Film Board of Canada, in its Montréal Headquarter, to acquire information and knowledge, not only from bibliographical references and articles but also from experienced professionals who work in this field on a daily basis.
The research consisted of a series of interviews with open questions with different professional figures of the NFB.
The interviews, which aimed to collect the specific point of view of all audiovisual production sectors, were later transcribed, analyzed, and integrated with external resources to draw up this document.

The following paragraph will better describe the National Film Board of Canada and its organization, and the reason why it was probably the best environment to gather information about this specific topic.

The National Film Board of Canada

Created in 1939, the National Film Board of Canada (NFB) is a federal agency under the Department of Canadian Heritage. Its mandate is to create, produce, and distribute distinctive and original audiovisual works that reflect Canadians' diverse realities and perspectives and to share these works with the people of Canada and the rest of the world.

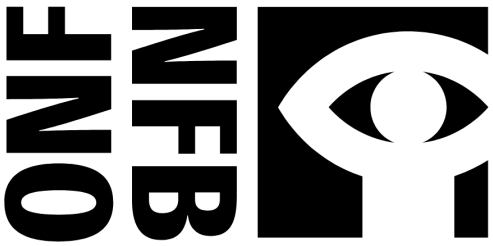

Figure 1. NFB Logo.

In their 2020-2023 Strategic Plan, NFB describes its short-term goal as:

"Creating new ways of storytelling for new ways of seeing: this is how the NFB contributes to this country. We give creators the opportunity to cast their unique gazes

on unexpected truths. We give audiences the opportunity to be touched, moved, and enlightened by original creative works. Through the NFB, Canada sees and discovers itself, in all its places and moods, in all its diversity and complexity. The NFB serves to further a human ideal, creating new ways of storytelling for new ways of seeing so that we can peacefully address the changes that are transforming the nation."

The institutional nature of the NFB allows putting creation and innovation on top of their priorities, defining a unique production model that offers creative spaces and allows incredible freedom of artistic expression to creators.
To support this model, technological research has always been a key factor in NFB's history to guarantee artists and creators the best tools for their work and develop new forms of storytelling.
It is not a coincidence that NFB was among the first to create an Interactive Studio that soon became one of the most important producers of interactive works worldwide.

What has been described until now points out the unique nature of the Board, which connects innovative production, technological development, distribution practices, and a long and eventful historical background. All those characteristics make NFB the best place to discover and analyze the past and the present condition of audiovisual production, and therefore the best place for this research.

NFB's Internal Structure

The NFB has eight production studios across Canada, divided into two programs, French and English.
English Program Studios:

- Animation & Interactive Studio - Montréal and Vancouver
- Quebec-Atlantic Documentary Studio - St. John's, Halifax, and Montréal
- Ontario Documentary Studio - Toronto
- North West Documentary Studio - Edmonton and Winnipeg
- BC & Yukon Documentary Studio - Vancouver

French Program Studio

- French Program Animation Studio - Montréal
- Québec, Canadian Francophonie and Acadian Documentary Studio - Montréal, Toronto, and Moncton

- Montréal Interactive Studio - Montréal

Interviews

Most of the research time was spent at the Animation & Interactive Studio at the Montréal Headquarter where, thanks to the NFB's Technical Director and Co-Supervisor of this project Eloi Champagne, I was able to meet professionals from different NFB's studios and departments.
List of Interviewees:

- Marc Bertrand - Producer, Animation Studio, French Program
- Jérôme Bretéché - Digitization Technician, Archive Plans
- Eloi Champagne - Technical Director, Animation & Interactive Studio, English Program
- David Christensen - Executive Producer, North West Studio, English Program
- Candice Desormeaux - Head, Technical Resources
- Laurianne Desormiers - Marketing Manager, Interactive
- Laurence Dolbec - Delegate Producer, Interactive Studio, French Program
- Jimmy Fournier - Director, R&D and Digital Platforms
- Steve Hallé - Head, Technical Resources
- Élise Labbé - Head, Festivals and Audience Development
- Robert McLaughlin - Executive Producer, Animation & Interactive Studio, English Program
- Donald McWilliams - Documentary Director
- David Oppenheim - Producer, Ontario Studio, English Program
- Louis-Richard Tremblay - Executive Producer, Interactive Studio, French Program
- Martin Viau - Technical Director, Interactive Studio, French Program

Part I

Production Process

Chapter 1

The evolution of production

This first section of the thesis is dedicated to the Production Process of Audiovisual works. It aims to investigate and understand how the production pipeline has changed in different kinds of content.

Before analyzing these differences, however, it is essential to know and comprehend some of the concepts of production that became standards in the Audiovisual world, particularly in the Movie Industry. To do so, I will be using the definitions of two movie production manuals, Producer To Producer: A Step-by-step Guide To Low-budget Independent Film Producing (Ryan [2017]) and The Complete Film Production Handbook (Honthaner [2010]).

The classical production process in the movie industry uses what is generally called the Waterfall approach. It divides the production into separate phases, and each of them cannot begin if the previous one has not ended. The phases are:

- **Development**: refers to the period of time and resources it takes to bring an idea to full maturation as a final script with total financing. This process involves the creative aspects of writing and revising a script and the legal steps of optioning or purchasing underlying material and procuring the proper releases and contracts.

- **Pre-production**: the period of time spent to plan and prepare for the shooting and completion of a movie. It is the time to schedule and budget, hire staff and crew, cast the film, and make all the artistic and financial decisions with all the different departments.

- **(Mid) Production**: the time of the actual shooting of the pre-visualized material. It involves all the crew members and all the actors on set.

- **Post-production**: the period of time needed to create the final product using the filmed material.. This phase consists of many different processes such as editing, sound design, soundtrack composition, visual effects, color grading, and more.

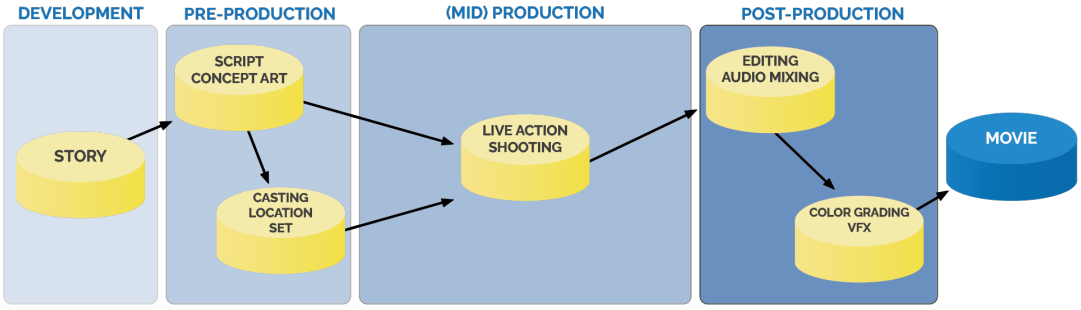

Figure 1.1. Classical waterfall production pipeline.

The following sections will define all the differences and similarities between this standard model and the production workflow of different kinds of audiovisual content.

1.1 The production process for fiction and documentary *flat* movies

The first kind of audiovisual content to be analyzed are fictional and documentary *flat* movies and short films. In this thesis, the adjective flat refers to the bidimensional nature of the image projected or lighted on a screen.
Throughout most of the history of Cinema, the production process of fiction and documentary flat movies has not changed much.
The division into the above-mentioned four stages is still the most used and most effective, although significant evolutions in technology have indeed influenced production over the years.

The Cinema Industry has always been a perfect example of how technology can serve the storytelling and the production of audiovisual content. Since its birth, technological research has been essential.
Therefore, before analyzing the most recent technologies, a brief historical overview of the innovations involved in movie and documentary production is in order to better comprehend the continuous innovative flow of the industry.

As well known, Cinema was born at the end of the 19th century with the invention of the French Lumière brothers: the *Cinématographe* motion picture system.
The first years of this recent medium are characterized mainly by experiments: noteworthy are Georges Méliès's works that laid the foundation of visual effects thanks to superimposition of images, fading, double exposures, and scale models. (Nowell-Smith [1996])

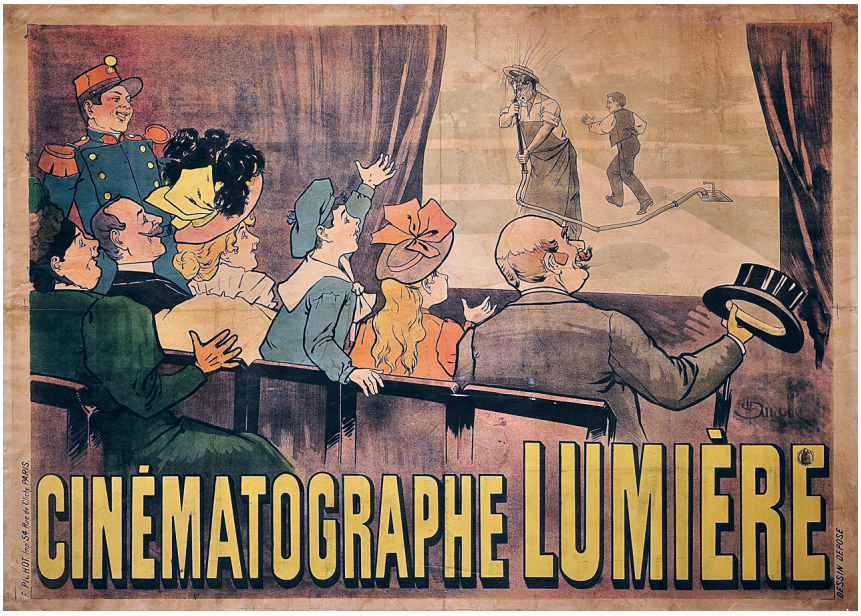

Figure 1.2. Poster advertising the Lumière brothers cinematographe.

The first cinema revolution started with the birth of the Production Studios and the affirmation of Cinematography as an industry in the 1920'.
This step was crucial for movie production, and led to some of the most important innovations during the '20s and the '30s. Significant examples are the introduction of the Technicolor three-color process between 1929 and 1932 and the use of synchronized sound, experienced for the first time in *The Jazz Singer*[1] in 1927.(Salt [1992])

For most of the 20th century, movie production standards remained the same. The evolution of technology permitted better results and pushed the limits of storytelling further. Most of those advancements involved shooting and audio equipment that became smaller and easier to use.

[1]The Jazz Singer (1927) - Directed by Alan Crosland - Warner Bros. Pictures Production

Consequently, new Cinema forms started to develop, far from Hollywood's standards, such as the Italian *Neorealism*, the French *Nouvelle Vague*, and the Canadian *Cinéma Direct*.

The invention of the television signed a critical challenge for the film industry, which reacted by moving the focus on the spectacularization of the cinema image and sound: examples of this tendency are CinemaScope first and IMAX later, but also Surround Audio and the introduction of 3D and stereoscopy.
Worth mentioning is the fact that some of the first IMAX innovations were realized in collaboration with the NFB, such as the multi-screen system used in Expo '67 for *Labyrinth*[2] or the first 3D IMAX system used for *Transitions*[3] in Expo '86.

Figure 1.3. Labyrinth's screens installation (1967) - NFB Blog.

Most of the 20th century saw various filmmaking changes, but the industry's future and practices seemed pretty stable and defined.
To quote NFB's Director and Editor Donald McWilliams, whose experience covered over 40 years of work in the Cinema Industry :

[2]In the Labyrinth (1967) - Directed by Roman Kroitor, Colin Low, Hugh O'Connor - NFB Production

[3]Transition (1986) - Directed by Colin Low - NFB Production

"I think the main prospect for the film industry's future was the idea that cameras would get smaller and easier to use, more or less like what happened with the so-called Super Eight revolution.
We always thought in terms of a refinement of the existing technology, and we had some intimations of a possible evolution of film with the videotape.
We did not think that somebody would come up with a notion of no tape nor film, except, I would assume, the futurists."[4]

[4]NFB's Director Donald McWilliams. Interview. Conducted by Giuseppe La Manna, May 2022

1.1.1 From film to digital: the first revolution

In the '80s, the diffusion of computers and digital technologies brought the most important and influential change in the movie industry.
The potential of digital production has been evident since its birth and has had a powerful influence in all the stages of audiovisual production. However, the most significant impact has been in (mid) production and post-production phases.

The digital technologies allowed the director and crew to have lighter and more performant equipment that did not need the film support anymore.
This was a significant change, especially for the documentary world, where creators could film with smaller crews in more hostile circumstances while keeping high-resolution footage.
Similar to the evolution of film cameras that led to the rise of Cinema Verité, digital equipment allows movies and documentary directors to express themselves more freely. An example is Werner Herzog's *Grizzly Man*[1]: the protagonist Timothy Treadwell, traveling only with his girlfriend and his very little digital equipment, was able to shoot sensational images of the Katmai National Park's wild nature and his interaction with grizzly bears, which Herzog used to tell Timothy's story and tragic death.

Figure 1.4. Frame from Timothy Treadwell's footage in *Grizzly Man*.

The more affordable and easier-to-use digital equipment also led to the democratization of content creation and to a new era of independent productions not usually connected to classical industry standards.

[1]Grizzly Man (2005) - Directed by Werner Herzog - Discovery Docs Production

Handycams, small digital cameras, and later smartphones enabled those who, until that moment, had only been consumers to become content creators and to tell their own stories and share them thanks to new digital distribution platforms (I.e., YouTube, Vimeo, Facebook).

Digital cameras also revolutionized the work on set: multiple cameras can run on the same shot to always get the best without wasting time on retakes. It also allows the director, crew, and cast to watch the filmed footage on set, allowing them to make changes and adjust details.
This technology defined new professional roles inside production crews, such as the DIT (more in chapter 3), and started the increasing overlapping trend between (mid) production and post-production. (Swartz [2004])

Thanks to on-set digital monitors and editing software, technicians can work on the just filmed footage, editing and color grading a rough version of the final cut. This also allows directors to have immediate feedback on the whole scene, reducing the possibility of future reshooting.
This has been a fundamental change, whose consequences will be analyzed in depth later in this document. Being able to move part of the post-production to an earlier stage of the waterfall pipeline was the first step that led to the definition of a new standard, where each phase does not need to wait for the end of the previous one to start.

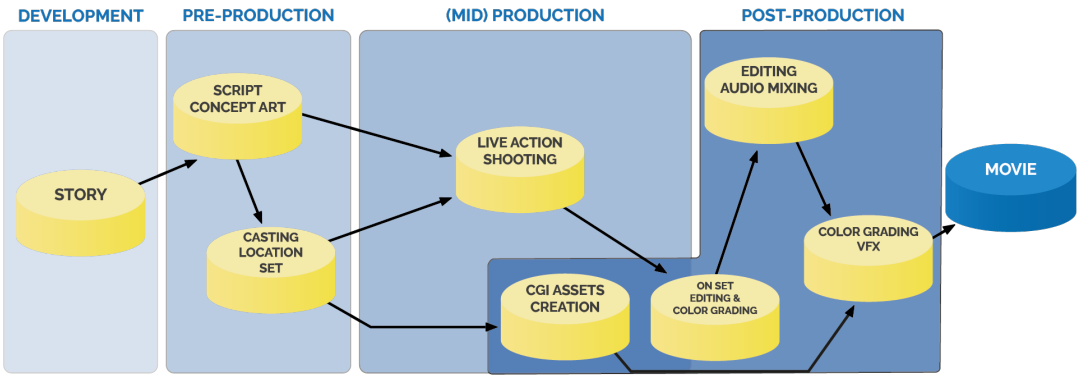

Figure 1.5. Digital waterfall production pipeline.

All this was possible thanks to the introduction of digital editing software, among all Avid Media Composer, Da Vinci Resolve, Adobe Premiere, and Final Cut, which revolutionized the post-production process, making the editing and color grading workflow much easier and faster.

However, despite what you might think, the digitalization actually led to an increase in time demand for post-production because of the birth of CGI.
Digital manipulation of images opened a whole new era for movie effects that, up until that moment, had been limited by the film, and usually involved on-camera tricks. If on one hand CGI provided filmmakers with new tools and instruments to create fantastic worlds and situations, on the other the high computing complexity of models, simulations, and effects caused the post-production workload and time to increase drastically. This caused the post-production phase to often become the most demanding in terms of professional, technological, and monetary resources.

1.1.2 From digital to virtual: production new frontier

Virtual production, or VP, is the latest, growing change in production. Before talking about VP, it is essential to clarify what it is. Epic Games defines it in its *The Virtual Production field guide*, written by Noah Kadner, as :

"A broad term referring to a spectrum of computer-aided production and visualization filmmaking methods.
...
VP combines virtual and augmented reality with CGI and game-engine technologies to enable production crews to see their scenes unfold as they are composed and captured on set." (Kadner. [2019])

Throughout this paragraph, Kadner's guide will be the primary discussion reference on this topic to analyze all the main VP attributes.

Kadner's first point addresses the problems of classical production and how VP can solve them.
He affirms that the classical production process resembles an assembly line encompassing development, pre-production, production, and post.
For filmmakers, this methodology manifests uncertainty because each phase is an overall process that feels disconnected and does not resolve until all shots are finalized. Finalizing occurs deep into post-production, when significant iterative changes are at best highly costly and at worst impossible due to a release deadline.
Virtual Production drastically changes the classical production approach, injecting into the workflow an Iterative approach that allows the Filmmaker and their crew to reduce uncertainty.
This process, according to Kadner, gives the production different benefits:

- It allows filmmakers and the department heads to iterate on visual details at an early production stage, not deferring these decisions to post.

- With a real-time engine, high-quality imagery can be produced from the outset. Instead of different teams creating incompatible assets from one another, assets are cross-compatible and usable from previsualization through final outputs.
- The editor can edit during principal photography so that the crew can immediately shoot pickups or make adjustments while shooting.
- Creating previs imagery in real-time unlocks the possibility to update sequences quickly and have outputs at a very high level of image quality.
- A real-time engine has the potential to eliminate many of the bottlenecks of budgeting, schedule, and development time that can slow down production.

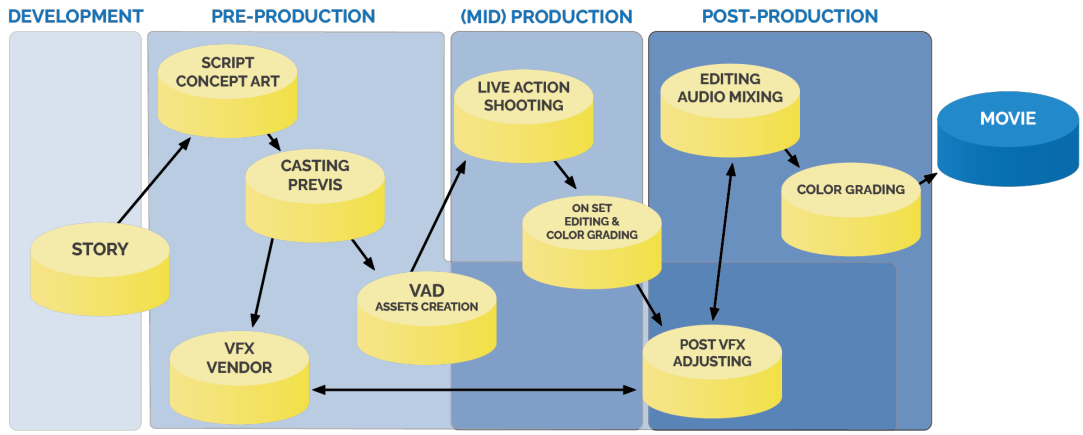

Figure 1.6. Virtual production pipeline.

Epic Games' guide also describes the different kinds of the VP in today's State of Art, dividing them into four categories: visualization, performance capture, hybrid virtual production, and in-camera virtual production.

The four of them consist of different techniques, some already established in the moviemaking world and others emerging, predominantly in the last few years.

Visualization

Visualization is probably the most familiar use of virtual production for most filmmakers. It can be defined as a prototype of images created to convey the creative intention of a shot or sequence.
It can take different forms, such as:

- **Pitchvis**: enables directors and designers to quickly produce an animated preview of the project to use during pitches and fundraising.
- **Previs**: is the basis of the visualization process. It is a virtual sandbox for creatives to explore creative ideas, including staging, camera composition, editing, and lighting, long before the final product is attempted. Its precursors are Storyboards and animatics.
- **Virtual scouting:** presents an entirely digital version of a location or a proposed set which crew members can interact with. The interaction might use an HMD (head-mounted display) or a computer screen.
- **Techvis**: uses 3D assets to perform technical analysis on scenes before getting on set.
- **Stuntvis**: a type of techvis tailored specifically to the planning of stunt work.
- **Postvis**: involves creating imagery merging live-action elements with temporary visual effects or creating new CG shots to provide placeholders for editorial.

Performance Capture

It uses Motion Capture (recording the movements of objects or actors and using that data to animate digital models) to convert the actor's performances into the virtual world. It includes both body capture and facial capture. The first uses suits covered in markers tracked by special cameras or a suit with built-in sensors; while the second involves the use of depth-sensor cameras for markerless facial capture or tracking markers on the performer's face.

Hybrid Virtual Production

Hybrid is the term that Kadner uses to describe camera tracking to composite green screen cinematography with CG elements. This standard has been predominant in the last few years. The two primary modes of hybrid virtual production are real-time, typically of medium-low quality with a locked-down camera, and post-produced.

Live LED Wall In-Camera Virtual Production

It is currently the most advanced form of virtual production: it uses an image output from a real-time engine to a live LED wall in combination with camera tracking to match the virtual camera movements to the real one.

There is no uncertainty for cast or crew compared to green screen cinematography. Everyone can see what is in the shot as it unfolds in real-time. The camera operator can frame as they would any real object, and the actors can react not to a marker representing a prop or a character but to the actual final imagery live in front of them. All of the natural reflections and lighting from the screen provide important artistic cues and enhance the realism of the imagery, compared to the typical struggle to avoid contamination from the green screen's color spilling onto the subject as well as creating unwanted reflections.

Figure 1.7. Mandalorian LED Wall set - ILM Official YouTube Channel.

As Epic Games' guide points out, projecting live imagery behind the actors to photograph effects in-camera is not something new. Rear projection effects via film projectors date back to the 1930s and were regularly used for vehicle driving shots. However, the LED Wall and the camera tracking via real-time engines allow the imagery shifts in perspective, creating a perfectly synchronized parallax to the camera. (Kadner. [2019])

Virtual Production is undoubtedly a powerful instrument that can carry plenty of benefits to movie creation in the hands of filmmakers.
However, it is not always the right solution or the best tool for all kinds of production, as each project has a different nature and optimal workflow, and it would be a mistake to try to siphon everything into a unique pipeline.
The real revolution in filmmaking is not about technologies, but rather about possibilities.

As a matter of fact, it is not possible to highlight a single standard in movie production anymore. The task of a modern producer is to understand and anticipate what the production needs and choose, among the increasing number of tools, workflows, and techniques, the one that best suits the project's nature.

1.2 The production process for Animated pictures

Animation historian Maureen Furniss writes in her book A New History of Animation: *"Animation is a term used to describe a broad range of practices in which the illusion of motion is created through the incremental movement of forms displayed sequentially as a "motion picture." Commonly, it is further divided into three subcategories: 2D Animation, typically employing a series of drawn or painted images; stop-motion, involving a puppet or other object that is modified in form or position over time; or 3D Animation, which has come to represent digitally produced images simulating deep space."* Furniss [2016]

The origins of Animated pictures can be traced back to the use of the *Magic-Lanterns*, *Fantasmagories*, and *Phenakistoscopes* during the 19th century, which simulated the movement of images and drawings in short loops.
Cinema's birth brought the conception of Animation, as described by Furniss, and paved the way to the definition of an industry in the late 1910'.

Animation production has been renewed and modified different times due to new technologies, techniques, and styles, but it has mainly maintained a Waterfall approach. Development and pre-production for Animation are characterized by the concept definition and story and style design, followed by the creation of a storyboard and an animatic, usually using the early version of soundtracks and voices to establish timing and scene transitions.
At this point, the actual production of the motion picture defined by assets creation and animation of characters and objects takes place.
Post-production for this kind of content consists mainly of stitching together all the created frames (in Computer Animation, this process is, in the great majority of cases, different) and adjusting colors and details.
The three categories of Animation listed above have taken different paths and underwent technical changes that influenced their production. I will analyze them separately, focusing on the main technologies and styles that transformed the working pipeline.

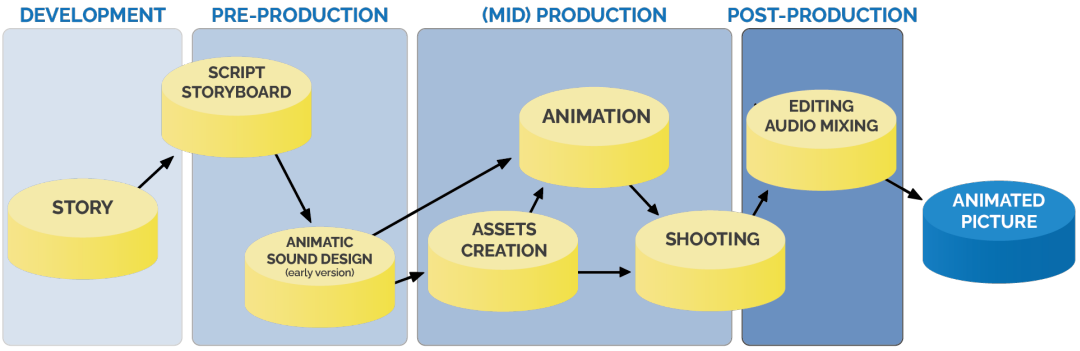

Figure 1.8. Waterfall production pipeline of animated pictures.

1.2.1 2D Animation

2D animation is the most known and used style of the last century. It consists of a series of 2D drawings of the character or the object that simulates its movements over time.

At the origins of animation, this technique involved drawing each animation frame. Obviously, this process took time and effort, so the early Animation industry developed a workflow.

The process that will be described is called cel animation and consists of a series of steps from the paper drawing to the actual camera shooting of the different frames. It has been the standard of the leading animation Studios around the world. The first step involves a key animator or lead animator, who is the one that draws the keyframes in a scene. The keyframes are the main poses within the character performance.
After the initial work of the key animator, the assistants would usually add details and some of the missing frames in the scene.
Once the key animator and the director approve the work, the clean-up animators re-draw the animation on clean paper, including all of the details of the original model sheets. This process makes sure to maintain cohesiveness and consistency in art style. Finally, the inbetweeners draw in whatever frames are still missing in between the other animators' drawings.
Once the animation is complete, the pipeline moves to the ink and paint process. Each animation picture is transferred to a transparent sheet of celluloid (or cel) using ink to trace the outline of the drawing. Once the drawing is copied on cel, it is colored. The transparency of the cel allows each character in a frame to be animated on a different sheet of celluloid, while the opaque background can still

be seen beneath all the cels. When all the frames are transferred on celluloid, the photography process begins. Each cel of the frame is laid on top of each other, with the background at the bottom of the stack. At this point, the composite image is photographed by a camera. Once the frame has been shot, the process is repeated until the end of the sequence. (Laybourne [1998])

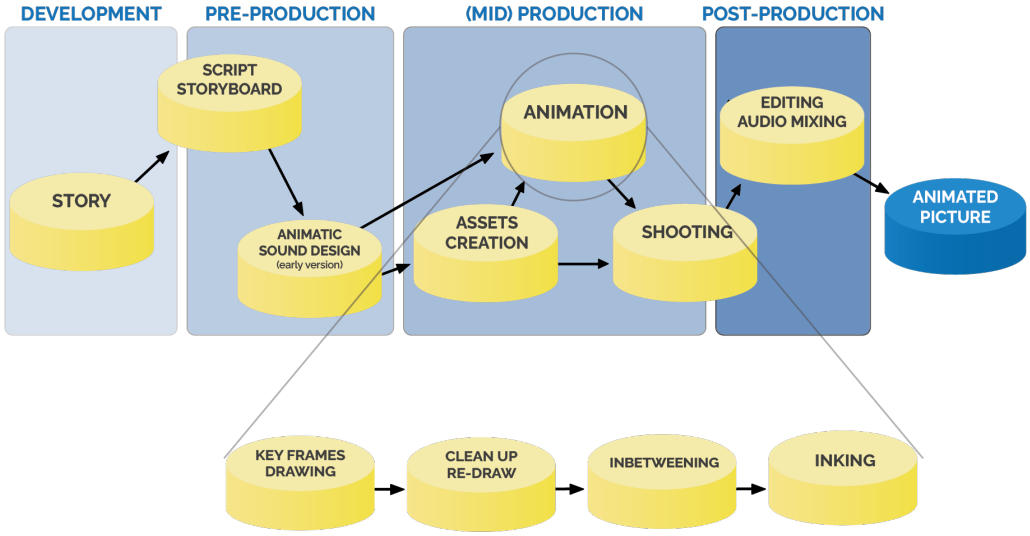

Figure 1.9. Detail of the production pipeline of Cel Animation.

The workflow described above did not change much over the years; the main difference between productions would be the number of people working on the sequence, frames per second, or the animation style, but nothing that drastically modified the pipeline.

However, some innovations allowed to speed up the process or increase the sequences' realism:

- The Multiplane camera, invented at Disney's Studio, helped animators solve problems with motion tracking and scene depth, reducing production times and costs for animated works (Museum [1933]).
- Xerography allows the drawings to be copied directly onto the cels, eliminating much of the inking process.
- Rotoscoping uses filmed actors, and then the animated frames are traced onto cel over the actual film footage. (Bedard [2020]).

Cel animation was undoubtedly the most used standard for animation Studios, but it was not the only one.

One of the problems with producing animation for television, for example, was the highly labor-intensive animation process. This led to a number of shortcut techniques to speed up the production process.
For instance, Hanna-Barbera furthered the concept of limited animation (also called planned animation). Characters were often broken up into a handful of levels so that only the body parts that needed to be moved at a given time would be animated. The rest of the figure would remain on a held animation cel. (Hanna [1996])

Another example is the French production of the animated series *Les ShadoksLes Shadoks*[1]. In this case, in order to speed up the animation process, they used the DeJoux's Animographe, a machine designed to simplify and accelerate the creation of cartoons. It consists of an animation table equipped with an optical system to animate 1 to 8 drawings per second while maintaining reasonable fluidity by making crossfades between consecutive images thanks to polarizing filters. It also used an instantaneous playback system allowing the animators to preview the artwork as it was created. (McLaren [1964])

As with live-action content, animation's great revolution also began with the digital age, when drawings could be scanned into the computer and filled with digital paint instead of being transferred to cels and then colored by hand.
The digital version can be composited in a computer program on many transparent layers and made into a sequence of images that can be transferred onto film or converted to a digital video format.
Although the waterfall approach was not affected by this change, the animation process was drastically streamlined by it, eliminating most of the tedious steps of cel animation.

The real revolution in the 2D animation process was brought by digital interpolation. In the mathematical field, interpolation is a type of estimation, a method of constructing new data points based on the range of a discrete set of known data points.
In animation, the discrete sets of known data points are the keyframes or the key points defined by the animator. The interpolation process does the job of the inbetweeners, mathematically calculating all the in-between positions of the character or object.
Clearly, this new practice changed the production pipeline, cutting out some of the steps of the traditional cel process and reducing production times and costs

[1]Les Shadoks (1931-2004) - Created by Jacques Rouxel

for animated works.

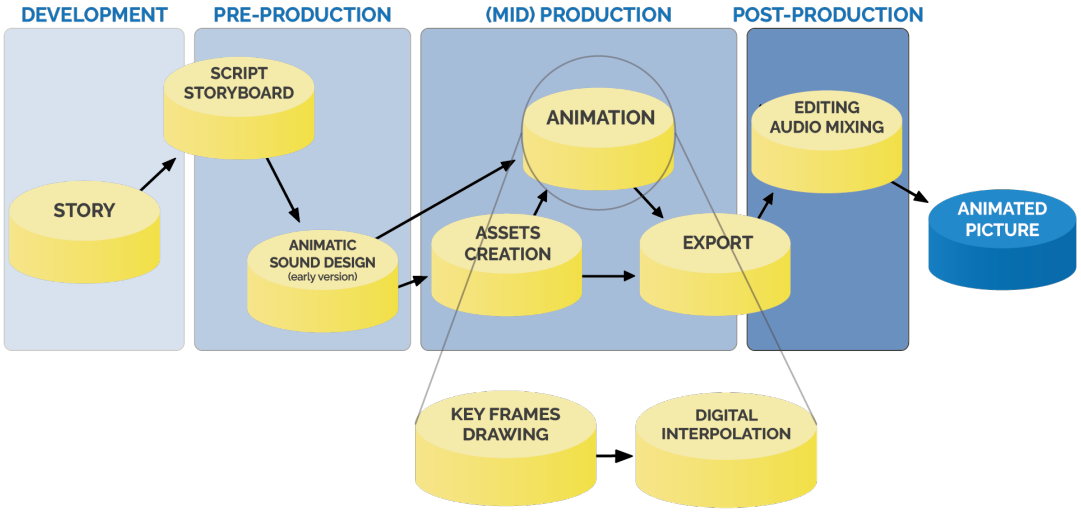

Figure 1.10. Detail of the production pipeline of Digital interpolated Animation.

Canada played a decisive part in this revolution, thanks to Canadian National Research Council scientists Nestor Burtnyk and Marceli Wein, who developed a revolutionary program that generated in-between frames that moved the action at 24 frames per second.
Their work led to the creation of the first computer-generated animated film to be nominated for an Oscar, Peter Foldes' NFB-produced *Hunger*[2].

Figure 1.11. Frames during digital interpolation transition in *Hunger*.

2D animation feature films have been produced less frequently since the introduction of 3D animation, which allows a faster and less expensive workflow (more

[2]Hunger (1974) - Directed by Peter Foldes

to follow). However, 2D is still used mainly in animated series and shorts and is very popular among film festivals.

1.2.2 Stop-Motion Animation

"Stop-motion is an animation technique in which an object is physically manipulated and photographed on a single frame of motion picture film so that it appears to move on its own. The object is moved in small increments between individually photographed frames, creating the illusion of movement when the series of frames is played as a fast sequence."
The definition above is from *A Century of Stop Motion Animation: From Méliès to Aardman* (Harryhausen [2008]),which examines the history of this animation technique.

Before focusing on the production process of Stop-Motion works, let's analyze some of the crucial steps and practices of this animation technique.
The origins of stop-motion can be traced back to Méliès's trick films which marked the invention of the stop-motion replacement.
However, one of the first examples of animation works using physical models (usually toys) was created by James Stuart Balckton and Albert Edward Smith in 1897, with *The Humpty Dumpty Circus*, a film considered the first to tell a story using animated three-dimensional objects.
At the beginning of the 20th century, puppets started to be designed appositely to be filmed and manipulated in front of a camera. They could either be made as toys with jointed limbs that could be moved, or with wired armatures covered with different materials: the first ones even used insect exoskeletons, but later on, they were replaced by light felt, leather, and rubber.

The history of puppets in cinema can be divided into their use in animated films and their use for special effects of movies (*Dynamation*), as happened for Cooper and Schoedsack's *King Kong*[3] and, later, for the first *Star Wars: Episode IV – A New Hope*[4] and Jurassic Park[5].

Stop-Motion can also use live actors. This technique is called *Pixilation*, a term coined by Norman McLaren, who used this technique for his short NFB-produced

[3]King Kong (1933)- Produced and directed by Merian C. Cooper and Ernest B. Schoedsack.

[4]Star Wars: A New Hope (1977) - Directed by George Lucas - Lucasfilm Production

[5]Jurassic Park (1993) - Directed by Steven Spielberg - Universal Pictures Production

film *Neighbors*[6], which won the Academy Award for Best Documentary. Pixilation is undoubtedly worth mentioning, but the Stop-Motion industry focuses more on puppets and object movement.

The use of clay to build malleable puppets played a significant role in the innovation of Stop-Motion, especially after the introduction of Plasticine with its peculiar characteristic of moldability, leading to the definition of a new style of animation usually called Claymation.
This technique has mainly been used in television in shows such as *Gumby*[7], *Morph*[8], and *Wallace and Gromit*[9].

Noteworthy is also the technique of substitution, which has been around since the beginning of the stop-motion medium but was largely used by George Pal. He used to carve entire puppets, switching them between the shooting of each frame instead of adjusting and repositioning the initial one. Pal called this technique *Puppetoons*, and several animators and directors began applying it only to replace single parts of the puppet, instead of all of it. For instance, in 1993, a combination of head replacement and foam injection to build the puppets' bodies was used in Selick's film *The Nightmare Before Christmas*[10].
Later, in 2005, Tim Burton's *Corpse Bride*[11] used another revolutionary technique in animating puppets' heads. The internal armature of the characters was built with a gear system that could change the puppets' expression underneath the silicon skin.

The production phases for Stop-Motion works are more similar to live-action production than 2D animation because of the material nature of the props and puppets. The pre-production phase mainly consists of assets and character creation from the previously developed concept arts, independently of the technique used for their creation.
The production phase cannot begin before all the assets and puppets of a scene are ready and consists of the actual shooting frame-by-frame of the action. Once all the frames are shot, the different scenes and sequences are composited together, and

[6]Neighbors (1952) - Directed by Norman McLaren - NFB Production

[7]Gumby (1953-today) - Created by Art Clokey

[8]Morph (1977-2021) - BBC and Aardman Animation Production

[9]Wallace and Gromit (1989-2008) - Created by Nick Park - Aardman Animation Production

[10]The Nightmare Before Christmas (1993) - Directed by Henry Selick - Touchstone Pictures Production

[11]Corpse Bride (2005) - Directed by Tim Burton - Tim Burton Productions

voices, music, and sound effects are added to the video (post-production phase).

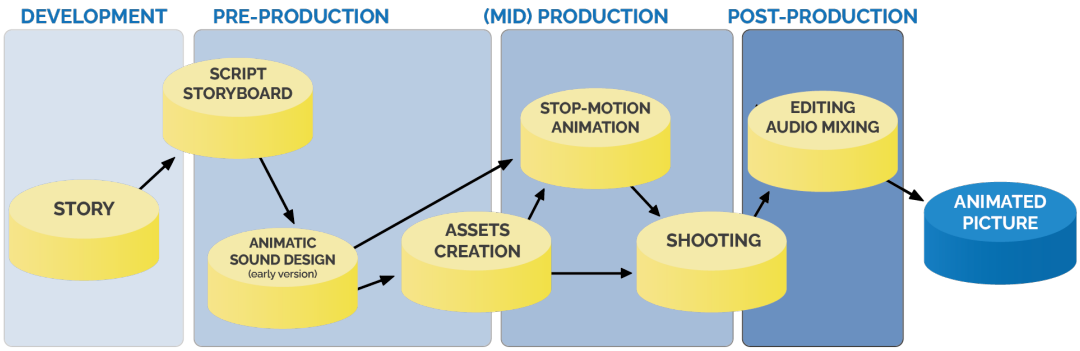

Figure 1.12. Waterfall Production pipeline of Stop-Motion Animation.

As with live-action movies and 2D animation, digital technologies also affected stop-motion animation production.
For example, a first game changer was LAIKA Studio's 2009 movie *Coraline*[12], directed by Henry Selick, because it required computer graphic support. In fact, it used 3D computer-printed models of replacement pieces, especially faces, designed in 2D on lip-syncing and actors' expressions and then modeled in 3D for the printing. It also used 3D generation of in-between positions and digital animation of entire animated face sequences. 3D printing technology is a helpful tool for developing replacement animation that allows working faster and more accurately on facial expressions and prop design, thanks to the help of digital technologies. However, this was not the only case in which computer graphic was required: CGI is largely used in stop motion for different purposes:

- Set extension and placing of environments via chromakey and masks;
- Digital editing to remove shadows and rigging instruments (allowing more flexibility in the movements for the animator);
- Application of effects such as motion blur for replicating the smooth movement of live-action;
- Digital substitution of puppets' body details in post-production phases.

Using digital tools allows the animators greater freedom, as they are not affected by the concrete constraints of gravity and budget to sculpt and build additional elements. Employing digital body parts, especially for faces, is a technique that

[12]Coraline (2009) - Directed by Henry Selick - Laika Production

saves time during the animation of the puppets giving the creators more artistic possibilities. As a result of the use of CGI, less time is spent on planning shots and building resources, hence pre-production times are shortened as part of the work is shifted and done during post-production.

A great example of the power of digital manipulation applied to stop-motion is the NFB's production *Madame Tutli-Putli*[13], directed by Chris Lavis and Maciek Szczerbowski, nominated in 2007 for an Academy Award. The characters' eyes are actually made of video footage of real human eyes, which were composited onto the faces of the puppets. (Maselli [2018])
Undoubtedly the effect of human eyes on the puppets achieved great success thanks to a facial expressiveness never seen in Stop-Motion. This technique is really used, especially in small or independent productions where the budget and time are limited.

Figure 1.13. Frames from *Madame Tutli-Putli*.

As for flat movies, digital tools help the stop-motion animators review the different shoots they took directly on set, giving them more freedom to try and redo. Thanks to software like Drangonframe, it is possible to step directly between live view and captured frames or switch to auto-toggle, loop playback to get the sense of movement, load multiple references and view them with the animation and more.

[13]Madame Tutli-Putli (2007) - Directed by Chris Lavis and Maciek Szczerbowski - NFB Production

Figure 1.14. Animation in Stop-Motion using Dragonframe - From *Out of Character* by Niccolò Gioia.

As already stated, a large branch of Stop-Motion production was connected to the visual effect world. Dynamation can also be used in the digital world. For example, during Spielberg's Jurassic Park production, a physical and motion-captured rig of a dinosaur was used to transfer the stop-motion animated movements from the rig to the 3D digital model of the beast. This technique is not very common nowadays, mainly because of the power of modern 3D animation software; however, giving the content a different look and fluidity can be an artistic choice.

Finally, one of the latest innovations in Stop-Motion production concerns Virtual Production. Similarly to what is happening in movie production, the introduction of real-time rendered images to use as backgrounds with LED walls or, in this case, even smaller HDR screens, can change the waterfall relation between production and post-production.
The idea is to use a high resolution and high dynamic range television, connected to a game engine, as the background with the possibility of tracking the physical camera's movements in the virtual set.
The reasons for preferring a virtual background to a post-edited greenscreen can be various:
First, it avoids keying and masks, permitting the puppets, which are usually made of felt or other materials, to keep a high level of detail in their outlines that would be partially or totally lost with masking.
The second reason regards lighting and reflections. The HDR background monitor that emits light allows the scene and the puppets to be lightened in coherence

with the world colors. To enhance the effect, it is also possible to put some more monitors all around the scene that could emit coherent lighting.
The third one is part of the stop-motion animation itself. Working in stop-motion is a straight-ahead kind of animation that can require the necessity of reshooting some frames. Having the whole scene in real-time in-camera allows the creators to modify and change setups, movements, and positions to get the best final result possible[14].

1.2.3 3D Animation

The term 3D animation identifies the process of creating three-dimensional moving images using 3D models of characters and objects placed in a digital 3D environment. An interesting characteristic of 3D animation is that it takes some aspects from both the worlds of 2D animation and Stop-Motion. Like 2D computer animation, it mainly works with a pose-to-pose approach, using the concept of keyframes and key points and creating in-betweens via interpolation. At the same time, however, it works with three-dimensional objects that instead of being physical puppets are 3D virtual objects.

The history of 3D animation is directly connected to the advancement of computer hardware and software and the evolution of CGI.
Among the first experiments in 3D animation, noteworthy are Edwin Catmull's works of the early '70s, such as A Computer Animated Hand, which worked out concepts that would become the foundation for computer graphics that followed. It is not a mere coincidence that Catmull went on to become a co-founder of Pixar.

The developments of early 3D animation are strictly connected to live-action productions that, in their early stages, invested in it to create new visual effects for movies.
For example, Star Wars and *Alien*[15] used wireframe model graphics to represent space ships' monitors.

In the '80s, Montréal was at the front run of Computer Animation with three

[14]TD Eloi Champagne's research interview about the NFB's production *Stick your Neck Out*, Directed by Eva Cvijanović and Faruk Šabanović

[15]Alien (1979) - Directed by Riddley Scott - 20th Century Fox Production

successful short 3D animated films. The University of Montréal produced two important works, both presented at the SIGGRAPH[16]: the first one is *Dream Flight*[17], considered the first 3D generated film telling a story, and the second is 1985's *Tony de Peltrie*[18].
In 1987, the short movie *Rendez-vous in Montréal*[19] was presented in Place des Arts in Montréal, which simulated Marilyn Monroe and Humphrey Bogart meeting in a café in the city's Old Town section. (Wikipedia [2022a])

The '90s reflected the previous tendency to use 3D animation and CGI as visual effects for live-action movies, for instance in *Terminator 2: Judgment Day (1991)*[20] with its *T-1000* CG-animated robot or the particular case of Jurassic Park's dinosaur mentioned above. However, the history of 3D computer-animated movies actually began in 1995.
The members of the ex-computer division of Lucasfilm, supported by the founder of Apple, Steve Jobs, created Pixar Studio, which in 1995 produced the first fully computer-animation feature film: *Toy Story*[21].
With Toy Story and the invention of Pixar's render engine *RenderMan*, the production of computer-animated 3D works resolved into a production standard that has been almost the same over the last years.

The main changes in technology from Toy Story until today mainly affected the quality of the works and increased the possibilities for creators to produce more elaborate and detailed worlds and actions.
Significant improvements in render pipelines, texturing, physical simulations, and particle systems defined the quality that we are all used to enjoying in modern animated films. The increase in hardware power played another essential role in this process, reducing render time and, at the same time, allowing more complex calculations.

[16]Special Interest Group on Computer Graphics and Interactive Techniques

[17]Dream Flight (1982) - Created by Philippe Bergeron, Nadia Magnenat Thalmann and Daniel Thalmn

[18]Tony de Peltrie (1985) - Created by Pierre Lachapelle, Philippe Bergeron, Pierre Robidoux and Daniel Langlois

[19]Rendez-vous in Montréal (1987) - Created by Nadia Magnenat Thalmann and Daniel Thalmanm

[20]erminator 2: Judgment Day (1991) - Directed by James Cameron

[21]Toy Story (1995) - Directed by John Lasseter - Pixar Studio Production

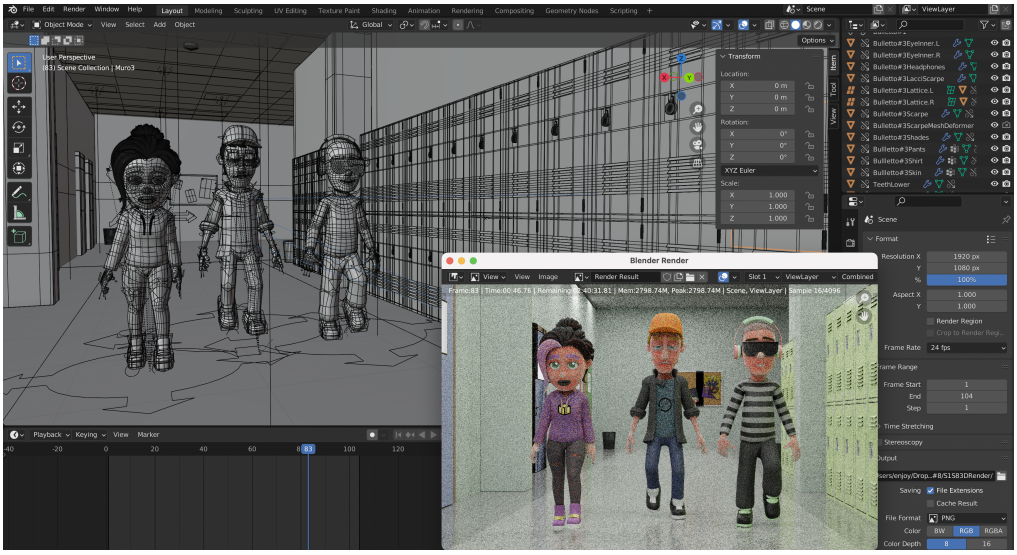

Figure 1.15. Frame rendering on Blender - From *Out of Character* by Niccolò Gioia.

Let's explore the production pipeline of this kind of content.
The original production process for 3D animated works maintains a waterfall approach. The development and pre-production phases are similar to the other kinds of animation: they are usually characterized by developing the idea into a script, creating a visual design for the environments and the characters, and all the previsualization work and timing definition with storyboards and animatics.
The production phase usually starts with creating the characters and the rigging process using 3D modeling software. Once the model is rigged, it is possible to animate it: the animation process generally uses a pose-to-pose approach, manipulating the position of each bone of the rig by using keypoints defined manually by the animator.
The position of each bone of the rig between two key points is calculated via interpolation in the 3D space. The interpolation process can calculate the in-between positions using different mathematical methods, each resulting in various movements, speeds, or accelerations in space.
While the animators work on the animation, different departments work on modeling environments and props, textures and shaders, physical simulations, and lighting and scene composition in a more advanced phase.

Once the production and the director are satisfied with a sequence, the next step is an intermediate phase between production and post, called rendering.
Rendering is the final process of creating an actual 2D image or animation from the three-dimensional prepared scene. It may take from fractions of a second to days

for a single image/frame, depending on the results the production wants to achieve.
The process described above uses a rendering technique called non-real-time because getting the final image usually takes time (Pixar estimates a rendering time per frame of 24 hours for its productions).
Once the final render of the sequence is finished, the process can move on to post-production, color grading, sound design, and editing.

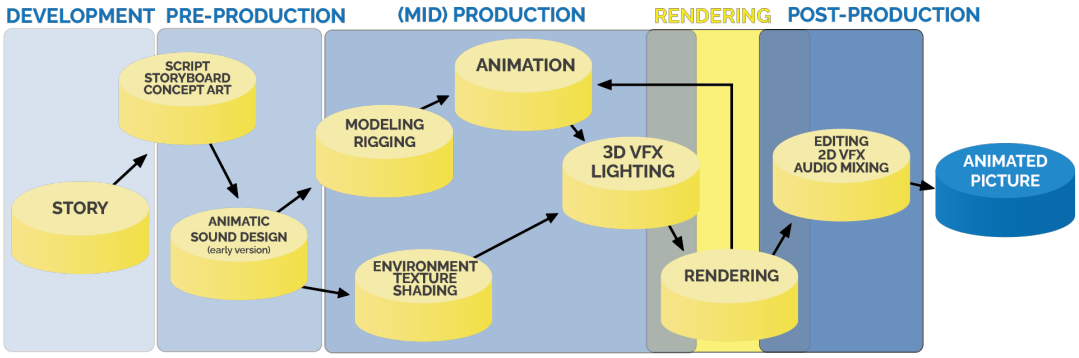

Figure 1.16. Production pipeline of 3D Animation.

The working pipeline involving non-real-time rendering is the most common and used because, until recent years, it was the technology that guaranteed the best results in terms of quality of lighting, texturing and simulations.
Waiting for a final render can result in a waste of time if it does not match the production's expectations or if the need to change something arises. In fact, once the image is complete, each frame in need of changes has to be rendered again, costing the production time and money.
For this reason, during the different production steps, the sequences are rendered at different levels of quality and completeness.
This approach allows the creators to intervene in an earlier stage in which the rendering takes less time than the final one.

Compared to live-action productions, this process seems to reverse what is done on a real set.
The first thing done on set is usually lighting the environment, then setting the cameras, then shooting the action, always having clear in mind how the shot will look.
In non-real-time CG-animation, this process is usually backward. This way, when filmmakers first see how the movie will look through layouts in a rough version of lighting and shaders, they could think of having made different decisions back in previous phases.

A complete solution to this process has been raised from the game industry during the past years. Videogames development has always needed a real-time rendering of the games' virtual worlds to be responsive and interactive for the players. However, the main issue with this kind of rendering pipeline has always been the images and simulation quality.
Nevertheless, thanks to hardware and software advancements, game engines such as Unity and Unreal Engine are now capable of rendering and displaying high-resolution environments and simulations in real-time and almost with no delay, bringing new opportunities to the animation world.

Epic Games and Unity Technologies have started developing entire areas inside their software to allow the creators to work on the whole animation process, from modeling, rigging, and animating to lighting and shading.
Creators can now work on sequences collaboratively among departments, making decisions in real-time, with no need to wait for renders to see the final result.

The production moves from a waterfall compartmentalized practice to inheriting the legacy of games development, where the main working method involves collaboration and iteration.
It allows production to avoid pushing data around with rough versions of scenes and sequences, reducing or eliminating the revising time and giving more freedom to filmmakers.

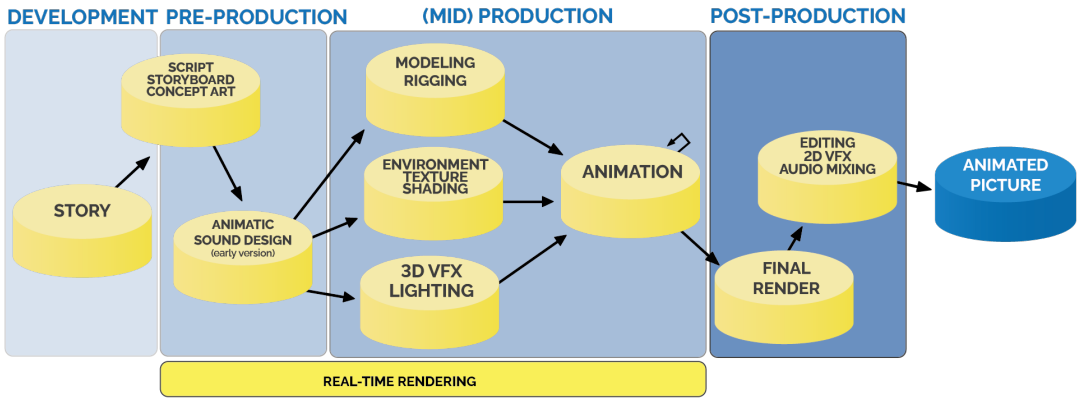

Figure 1.17. Production pipeline of 3D Animation with real-time rendering.

Another great advantage of working in Computer graphics with game engines concerns the possibility of easily going transmedial.
Game engines allow creating open worlds and big assets that can be used on different kinds of platforms or repurposed for spin-offs or sequels with minimum changes. This approach can save time and especially money if the idea of the

project is to create a franchise; however, it is a factor to be taken into consideration from the beginning of production; it cannot be an afterthought. (Pulse [2021])

In this paragraph, different methods, practices, and approaches to various kinds of animation have been discussed. Technological developments have undoubtedly influenced the possibilities for creators, filmmakers, and amateurs; however, it is essential to recognize that Animation is a form of art, and as such, it is about creativity, storytelling, and people.
Technology only gives creators the tools and instruments to express themselves, but it cannot be the protagonist.
As seen for movie production, it is impossible to define a form or technique that is generally more suited or powerful than another, as the working tool's choice depends on each project, goal, and creative vision.

1.3 The production process for Interactive and Immersive works

The last category of content to be analyzed is Interactive and Immersive. Throughout this paragraph, I will use the definition of nodal media for Interactive works: in a narrative, a *node* is a situation that allows for more than one continuation. In terms of media, a vehicle that is actively nodal allows the audience to make choices that alter the outcome, while one that is passive prohibits outside interference in its rules. (Dietrich [2013])
This definition includes web-based projects, interactive digital installations, and immersive VR, AR or XR works.
The essential characteristic of this definition is that the content needs to tell a story without interruptions and that the user's actions influence its perception or the flow of the narration.

The categorization of videogames as interactive storytelling has been largely discussed by narratologists and ludologists.
One side claims that a large part of the presence of narrative in video games is constituted by forms that the player cannot interact with. These are mainly textual narratives (written and spoken, such as log-books, letters, or audiotapes) and cinematic narratives called cutscenes. While these are very effective in creating a narrative, they often rather heighten the divide between narrative and gameplay. (Domsch [2013]) Moreover, not all games focus on narrative; sandbox games, simulation games, and sports games do not need a story or context behind them.
On the other side, considering the definition of nodal narrative, some videogames offer the possibility to modify the story's outcome with actions and choices: they

use dynamic systems for interaction because much of the narrative content can be related to the player's actions. The main forms under consideration here are quick time events, dialogue trees, and event triggers. (Somerdin [2016])

Ultimately, videogames contain both kinds of narrative that Sebastian Domsch defines as passive narrative forms and actively nodal forms (Domsch [2013]). However, for the purposes of this thesis, I have decided not to consider videogames among the Interactive and Immersive works because of two main factors:

- The ambiguity in the classification of videogames as interactive narratives, as seen above.
- The videogame industry is much more stable in its production process than the audiovisual industry. The considerations on its workflows and pipelines would be different compared to the changes in production for Interactive and Immersive experiences.

However, some practices and tools from the videogame industry will be essential to define new practices for Interactive productions.

Early attempts to create digital interactive storytelling date back to the '60s and '70s, when the introduction of laser disk technology enabled the user to access high-quality imagery on the computer screen, and the concept of the GUI[1] allowed the user to interact with the computer in a more intuitive way.

The development of Macromedia Director/Shockwave or Apple's HyperCard in the '90s allowed multimedia content to be used in apps distributed on CD-Roms. They were the basis for some of the earliest interactive software and games, such as the *Encarta encyclopedia* and *Myst*.
The growth of the internet in the mid-90s meant that tools were needed to provide similar content in web browsers.
The instruments used until that moment could not transfer the quantity of data they dealt with via the world wide web due to its limited bandwidth.
The problem persisted until the invention of Macromedia Flash Player in 1996.
This system could generate vector-based animations using much less data than bitmap animations since vectors only needed to describe the relationship between points, colors, and other information. This allowed Flash to become the perfect instrument for the early internet.
Flash was the leading multimedia platform for several years. In 2000, ActionScript, an object-oriented programming language, was added to Flash, allowing developers to script actions rather than animate them, enhancing the available

[1] Graphical User Interface

content types, including web games and streaming media.
In 2005 Adobe added Flash to its Creative Suite. Since HTML did not have direct support for videos, Flash was the perfect instrument to download and watch video content online, being an easy-to-install browser plug-in. The potential of the web and Flash led to the creation of some of the most successful interactive works; creative Studios worldwide started to work with interactive documentaries and stories. (McElhearn [2020])

Among those, in 2008, the National Film Board of Canada created the Interactive Studio, helping to position Canada as a major player in digital storytelling. NFB's web-based interactive works received positive feedback from the critics and gained different prizes among the newly created festival categories for those new kinds of content.
One of the first NFB's interactive works is *Late Fragment*[2], co-produced with the Canadian Film Center, considered North America's First Interactive Feature Film. Flash was undoubtedly a powerful tool, but security issues and compatibility problems with the newly born smartphones (especially iPhones) caused the slow decline of the platform.
In 2010, Steve Jobs, in an open letter (Thoughts on Flash), pointed out the many reasons why Apple would not allow Flash on the iPhone. These included reliability, security, and performance.

Because of these many security vulnerabilities, Adobe was often required to issue updates to Flash Player. By 2011, Flash Player was no longer included with Mac OS X, and users had to download it to view Flash content on the web, but most of the time, the installers revealed themselves as malware.
Meanwhile, YouTube developed HTML5 and created its app to be able to work on Apple products not relying on any external service.
Finally, in 2017 Adobe announced Flash's end of life by the 31st of December 2020, giving developers the time to change their technology. (McElhearn [2020])
The disappearance of Flash caused the loss of most of the interactive works based on its platform. However, some studios and institutions tried to preserve their productions and the legacy of their works, converting the projects into new platforms or saving the code.

Another form of interactive storytelling can be found in installations. The Interactive Art installations concept is really vast: this category can include all

[2]Late Fragment (2007) Created by Daryl Cloran, Anita Doron and Mateo Guez - NFB & CFC Production

kinds of installations that somehow involve actions from the viewers.
For the research purposes, I will consider only the kind that features computers, interfaces, and electronic sensors.
One of the first examples of these kinds of artwork is *Glowflow*[3], created in 1969 by Myron W. Krueger, which consisted of a space with pressure-sensitive sensors on its floor, loudspeakers in the room's four corners, and tubes with colored suspensions on the walls. The visitor who stepped on one of the sensors set off either sound or light effects. (Krueger [1977])

The technological evolution of sensors, computers, and equipment and the introduction of CGI and digital image manipulation allowed the creation of more complex installations and exhibitions.
Recently, interactive installations are focusing on a digital technology that is becoming really popular: Virtual/Augmented/Mixed Reality.

The term Virtual Reality refers to a simulated experience of a user in a virtual world. This technology uses visors, monitors, or projectors to display the synthetic world and operates with sensors to allow the user to interact with it.

The first technological experiments in Virtual Reality can be traced back to the '60s when Morton Heilig introduced the Sensorama. This immersive, multi-sensory mechanical machine displayed films while engaging different senses (sight, sound, smell, and touch).
Today VR standards systems use mostly head-mounted displays or HMDs. The first HMD system was created in 1968 by Ivan Sutherland. The visor was so heavy that it had to be suspended from the ceiling. Due to its strange appearance, it was named *The Sword of Damocles*. The graphics of the virtual environment were simple wire-frame model rooms. (TWTD [2020])

From The Sword of Damocles, most experiments on VR technologies were conducted within the scientific and academic fields.
In 1973, thanks to the first graphic accelerator, it was possible to produce synthetic images. Meanwhile, MIT designed the *Aspen Movie Map*, which allowed the exploration of the city of Aspen through pre-rendered images and polygon 3D models.
In 1979, 3Space was released as the first non-contact tracker, with 6 degrees of freedom, thanks to variations in a magnetic field.

[3]Glowflow (1969) - Created by Myron W. Krueger

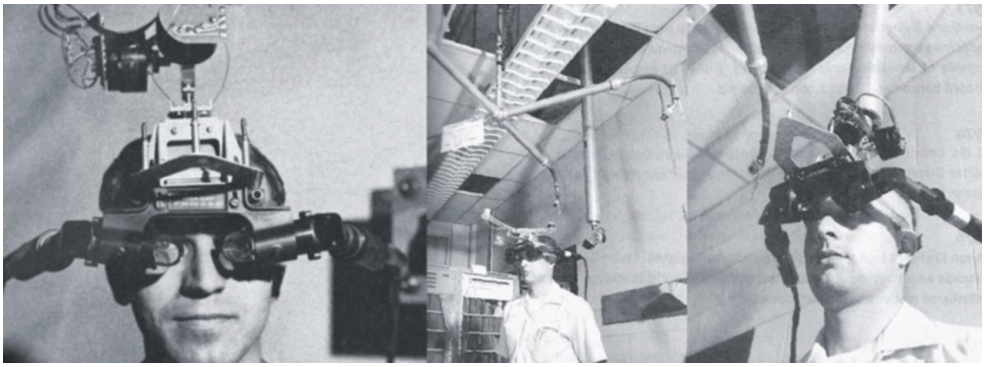

Figure 1.18. *The Sword of Damocles.*

During the '80s, the videogame industry took an interest in VR as a new gaming interface. Those were fruitful years in which some of the most powerful video games companies invested in VR technology. Jaron Lanier's VLP developed VR devices like the *DataGlove*, the *EyePhone*, and the *AudioSphere*, and Nintendo produced *Mattel's PowerGlove*, which used ultrasonic sounds to detect the user's hand movements. (Wikipedia [2022b])

Despite the initial excitement for this technology, the high production costs and low quality of movement detection and virtual worlds reproduction led to a loss of interest in VR, stalling its development.

At the beginning of the 21st century, the introduction of more affordable but more powerful graphic cards, the proliferation of home computing, and the possibility of creating more accurate sensors led to the game industry's new interest in VR.
In 2010, Palmer Luckey designed the prototype of the *Oculus Rift*, a 90-degree field of vision HMD later acquired by Facebook. Oculus relaunched the interest in HMD VR, and from 2014 game development companies such as Sony and HTC started to invest in this technology.
Meanwhile, the evolution of smartphones and portable devices enabled the development of VR-related technologies such as Augmented Reality and Mixed Reality. (Schnipper [2017])

The game industry's excitement for Virtual Reality quickly spread to other fields. Storytellers, directors, and artists saw VR as a powerful instrument to tell stories and started to produce works for this new medium.

The Virtual Reality discussed until now is a direct consequence of the interest of the game industry in this field; in fact, it involves extensive use of game engines, coding, and computer graphics.
However, advances in the technologies used to capture 360° images provide an opportunity for filmmakers to leverage 360° video to apply the techniques of cinema to VR.
This is not VR in the previous sense; it is viewing a film within a VR headset and experiencing the story inside the narrative world. This melding of cinema and virtual reality gave rise to a new term, Cine-VR.
Compared to the more traditional VR, Cine-VR is a new medium in its infancy and it is essential to recognize that there is still so much to learn and room to explore in its grammar, techniques, and processes.

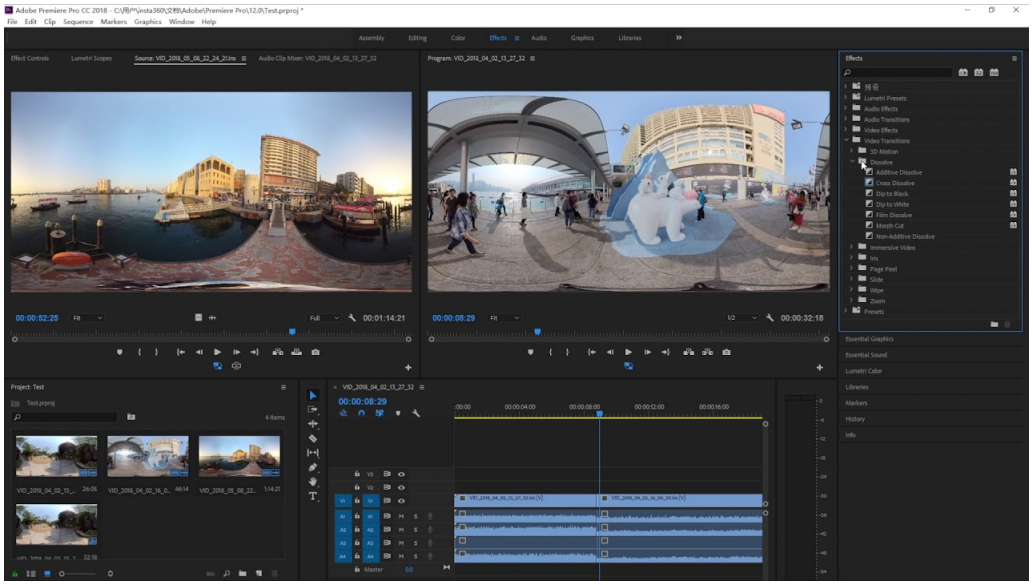

Figure 1.19. Editing 360° video on Adobe Premiere Pro CC - Insta360.

However, some of the aspects and methods of Cine-VR can already be highlighted:

- The concept of gravity: everything revolves around the camera in a 360° scene. The camera is the center point, and the more the scene progresses, the more important aspects of the scene should be drawn towards the camera as if it were the center of gravity.
- The user's control: since cine-VR is a 360° image, and since it is impossible to view the entire 360° space simultaneously, it is unlikely that anyone will have the exact same experience in cine-VR. Each time, we choose different things to observe or to observe them in a different order. Therefore, each experience

is unique. Furthermore, if each experience is unique, then the audience's choices while in cine-VR affect their outcome. In essence, each person crafts their own experiences by the choices they make regarding what to watch and when to watch it.

- The importance of audio: given that the viewer will only be able to see approximately one-fifth of the available visual content, the value of being able to call their attention with audio cannot be overstated. It is possible to do so with spatial audio formats, an experience where sounds remain locked to a specific portion of the video, regardless of where the audience is looking.

- New steps for editors: Cine-VR involves some new tasks for editors, such as the Stitching process (taking the different images captured with a 360° camera and combining them in an equirectangular or stereoscopic image) or the reorientation of the image (focus the user view on the wanted plate).

(Williams-Love-Love [2021])

Among those analyzed, the production of Interactive and Immersive works is the one that shifts the most from the Waterfall approach of movie production. Interactive projects inherited most of their production pipeline from software development because of their evident dependency on coding.

The main approach used in Interactive productions is the *Agile Methodology*[4] and, although used in different fields, it comes from software development.
Agile creates a project management workflow focusing on continuously delivering small pieces of work to get quick feedback. This allows Agile teams to adapt to emerging changes that inevitably occur in most projects.
A popular variant used in game development is called *Scrum*[5].
Scrum organizes teams into small cross-functional groups. These teams prioritize their work each day and embrace iterations.
This methodology is appropriate for game or VR environments because the ability to change fluidly is essential for solving complex design problems. Big productions organize Scrum teams around the experience features. This allows a large number of creative people to work effectively on a project without the burdens of too much top-down management.
Rather than having the team follow a detailed specification created up front, developers will address the priority features to set short-term goals and work together

[4]https://www.agilealliance.org/agile101/

[5]https://www.scrum.org/resources/what-is-scrum

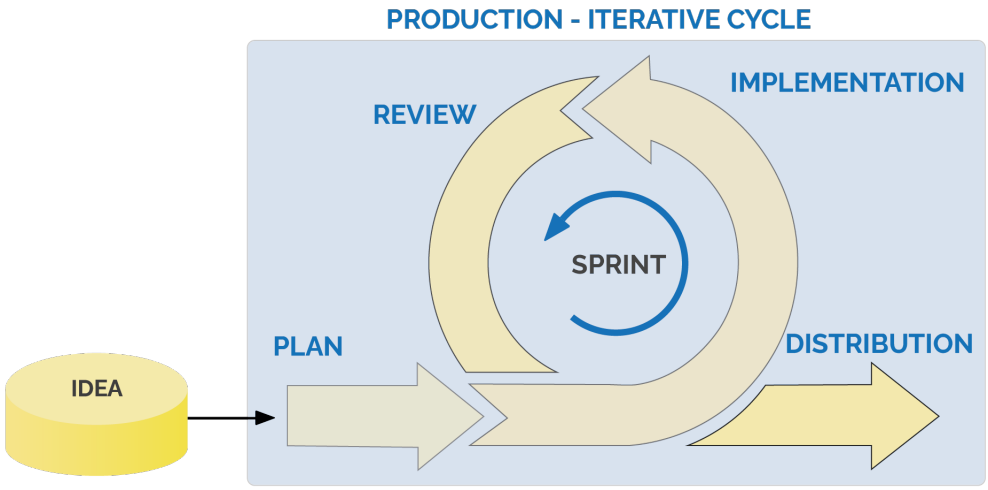

Figure 1.20. Agile Methodology production.

closely to implement those goals in short periods called Sprints.
Daily or weekly meetings can be used to evaluate progress, set new goals, and determine if there are gating issues to progress.
There are several important techniques to lead effective Agile teams, but these three are critical to the methodology:

- Working in Sprints: Sprints are fixed-length goals for working project iterations. The Sprint goals should be clear and doable and result in a working build that can be evaluated by the team and playtested by testing users.
- Holding Scrum meetings: Scrum meetings are short meetings where the team members show what they have accomplished, set goals for the following day's work, and discuss any obstacles keeping them from accomplishing their goals.
- Prioritizing and working on features based on input from potential users: the producer or product manager owns this list of features and makes decisions with the team about how these features are prioritized.

(Fullerton [2018])

Within the Agile and Scrum Methodologies, NFB's French Interactive Studio, based in Montréal, has conceived a division of the production's tasks into three core lines, each identifying a different aspect of the content's production.
It is possible to visualize it using a triangle: at the center of the triangle sits the project, and on its three corners are located the teams:

- The first team is in charge of the creative/editorial pipeline. It usually includes the person, or the group of people, who developed the original idea. They focus on the creative aspects of the work, defining the storytelling and the narration, elaborating possible ways of user interaction and the dynamics of the experience.

- The second team is in charge of the technologies involved in creating the project. They work on the back-end of the application; for this reason, it is usually formed by programmers and software developers.

- The third team works on the experience design. It is in charge of the front-end part of the application, defining and building the best interface to interact with the narration. It is usually composed of coders, 3D artists, and visual designers.

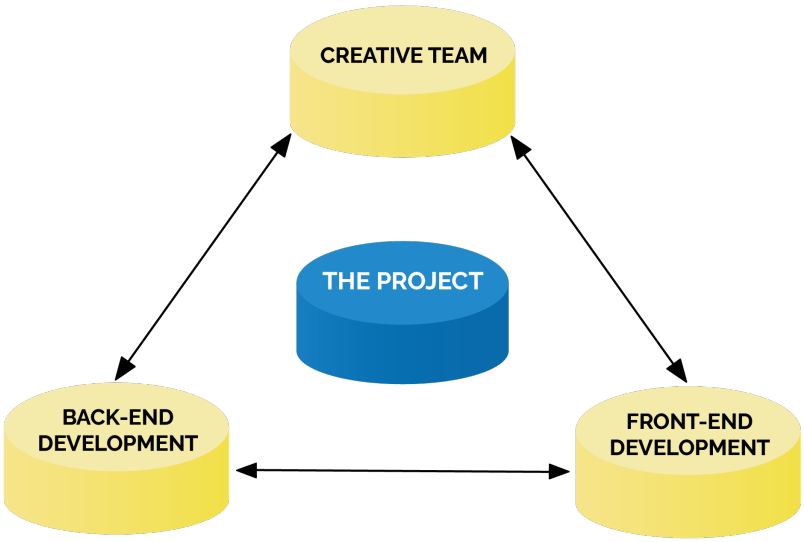

Figure 1.21. The Triangle system.

The three teams can simultaneously work on different aspects of the experience during the same Sprint.
However, constant communication is essential to keep track of each team's achievements and advancement.
Each Sprint can either work on new features or merge the work of the previous iterations, depending on the phase's goals.
Sets of Sprints can lead to the creation of different prototypes and consequential

versioning[6].

To better explain how the triangle works, it might be helpful to provide a practical example. I will be using a currently work-in-progress NFB production: Chomsky vs. Chomsky.
This VR experience is a co-production between NFB, Schnellebuntebilder and Eye-SteelFilm.
NFB, on its website, describes it as:

"This project seeks to raise AI literacy by informing us about its potential and limitations, all while reminding us of what's special about human intelligence. Chomsky vs. Chomsky aims to provide a playful and introspective interaction rather than an intellectual experience. Guided by no other than CHOMSKY_AI, our virtual host built from digital traces of Noam Chomsky, we're invited to think about the quest for AI—what we're told it can do and, perhaps above all, what we want it to be."

The experience consists of an AI that, after learning over 60 years of interviews, videos, and works from the linguist and cognitive scientist Noam Chomsky, can engage the user in a conversation using a deep-fake system simulating Chomsky's voice. Meanwhile, thanks to a VR headset, the user is immersed in a virtual and interactive world where this conversation takes place.
The project already has almost four years of work behind, and it is planned to be released in November 2022 in Berlin as an installation before it becomes accessible on other platforms.
The production works on the project using the "triangle system" mentioned above.
The creative team is led by the sociologist of media technologies Sandra Rodriguez, who conceived the project's original idea.
The German Studio Schnellebuntebilder manages the front-end; they are working on the virtual world's design and interactions.
Coder and artist Cyndy Bishop is developing the back-end side of the experience; her task is to create all the connections between the AI and the game engine.
This project involves a fourth team that can be considered a satellite around the production triangle: it is Moov ai, an AI service provider that works on developing the Chomsky_AI[7].

[6]NFB's French Interactive Studio producer Louis-Richard Tremblay. Interview. Conducted by Giuseppe La Manna, May 2022

[7]NFB's French Interactive Studio producer Laurence Dolbec. Interview on Chomsky vs. Chomsky. Conducted by Giuseppe La Manna, May 2022

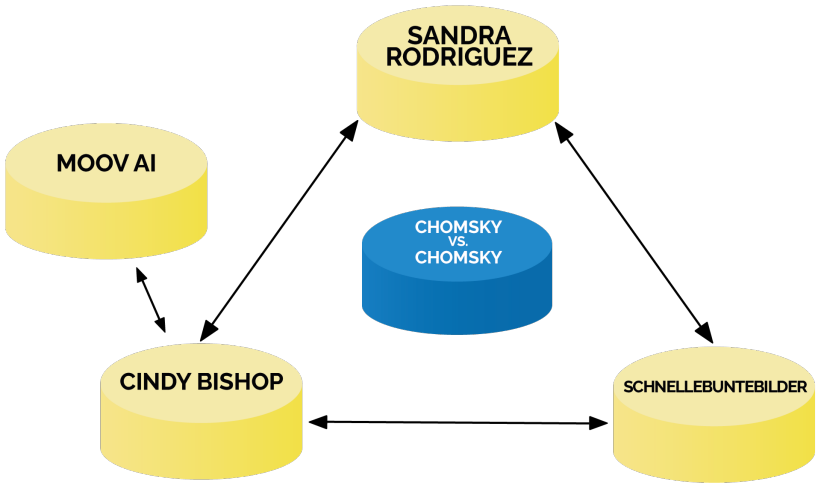

Figure 1.22. The Triangle system applied to NFB's Chomsky vs. Chomsky project.

The triangle system was essential to this project due to the complexity of the work and the physical distance between the teams. The production used an iterative and collaborative approach based on constant communication.
The team built a prototype to test the potential of the simulation, which was also used to create a 10-minute prologue of the VR experience: Chomsky vs. Chomsky: First Encounter. The prologue was presented at the 2020 Sundance Film Festival in the New Frontier section, where it has been largely successful, raising the expectations for the November 2022 release.

Figure 1.23. *Chomsky vs. Chomsky: First Encounter* - NFB Blog.

1.3.1 The introduction of the Product Lifecycle in Audiovisual Content

Interactive and Immersive productions have a characteristic that more traditional formats do not share.
Software development standards usually define a Product Lifecycle.
Two main phases usually characterize this cycle: the first one is called Development Phase, and the second is the Release Phase.

Traditional audiovisual works, such as animation and live-action movies, share with this vision only the concept of a development phase, because they see the release as the goal and the end of the production process, after which the only concerns are marketing and distribution.

In software development, the release of a product does not correspond with the end of production; on the contrary, it starts a new production phase characterized by maintaining and updating the program.
Due to their connection to software and hardware technologies, Immersive and Interactive projects share this phase.
Release and maintenance usually involve different aspects, such as the allocation of digital or physical space for the project material or the equipment on the platforms or places that allow the fruition or physical maintenance of hardware involved in the experience.

While talking about the evolution in production, it is essential to highlight how post-release production influences the budgeting and the allocation of professionals during the stipulation of a contract.

For example, a rough estimation of maintenance costs for an interactive project over a period of four years can go from 2% to 10% of the entire production budget. The exact expense depends on the characteristics of each project, its interface, and its dependency on external resources[8]

The previous consideration leads to another familiar concept in software development: the End of Life of a product.

[8]NFB's French Interactive Studio producer Louis-Richard Tremblay. Interview. Conducted by Giuseppe La Manna, May 2022

This notion does not apply to traditional formats, which after their release, can be watched on different platforms and devices with the only condition of existence of a copy of the content (either digital or physical).

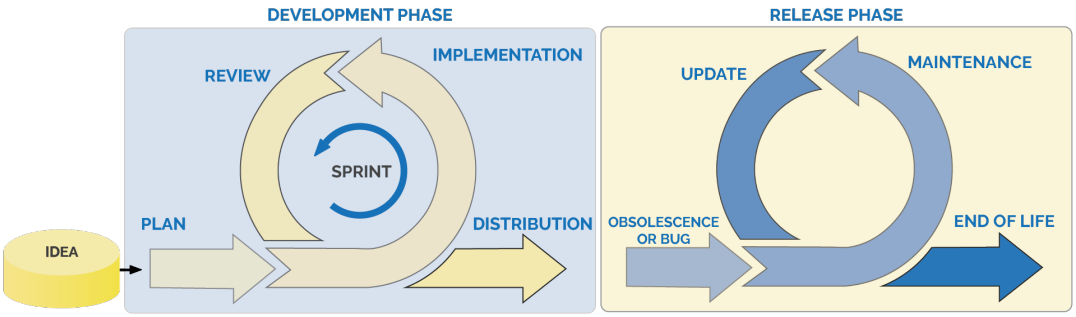

Figure 1.24. Agile production and Life cycle of an Interactive work.

For software, the End of Life implies that it is no longer sold or supported, and therefore discontinued, retired, deprecated, or abandoned.
For Interactive works, it can even mean the total impossibility to access and experience the content, as happened in the case of most Flash-based web works.
The End of Life date of an Interactive project is a factor that needs to be taken into consideration in an early stage of development to be able to allocate, in advance, the necessary financial and professional resources.

Part II

Professionals

Chapter 2

New professionals and new tasks

The audiovisual industry standards developed during the years generated very well-defined jobs and expertise; filmmaking manuals often show the traditional division into departments and the professionals' hierarchical organization in each production phase. We are used to hearing about directors, producers and all sorts of audiovisual industry workers.
In countries such as the US and Canada, the standardization of cinema professionals led to the creation of very specific guilds and unions to represent their members in negotiations for wages, benefits, working conditions, royalty payments, and other issues.

However, the changes in the production workflow analyzed in the previous chapter implicate evolutions and modifications in the tasks and roles of most figures working on audiovisual content.

First of all, the three content categories seen above are facing a gradual contamination from the software development world, not only in their procedures and practices but also in the people involved in the production.
In filmmaking and animation, the increasing importance of virtual technologies requires the introduction of figures such as programmers, virtual artists, 3D modelers and new kinds of technicians.
Content Productions need to adapt to the injection of those new figures facing the challenge of merging two worlds that, until now, have worked with totally different methodologies.

While some working figures are being introduced, others are evolving and changing; most of the jobs now tend to be specialized more deeply in a particular field of their work.
It is common to see long end credits in movies where the number of people in digital and virtual departments is really high. It is a symptom of the above trend; in fact, in those departments, people are specialized in very particular features, such as lighting, texturing, physical simulations and more.

To be precise, the movie industry has already faced the first step of this evolution with the introduction of digital technologies, and despite the expectations that such a standardized sector can raise, it has proved itself able to accept and embrace the innovation.

In the following section, I will go through the classical organization of an audiovisual production crew, focusing on the differences caused by the influences of new technologies, formats, and practices.
To do so, after a brief introduction to the profession from T*he Complete Guide to Film and Digital Production* (Wales [2017]), all the considerations about its changes will be a result of the research interviews with audiovisual professionals conducted at NFB.

2.1 Producer

The Producer is the person on a project responsible for everything: the process, the budget, the people and, ultimately, the final product, whether it be a feature film, documentary, interactive content or installation.
The Producer must have the ultimate vision for what the project needs to be and the ability to communicate it to the director or the creators.

The changes in the industry are not modifying the nature of the Producer's role; however, they are facing the challenge of dealing with new experts whose backgrounds differ from traditional audiovisual specialists.
Their new task is to assist and facilitate the communication between those two merging worlds.

To do so, today more than ever, the Producer needs to understand the language of the medium and the technology they want to choose in the production process. In the past, audiovisual practices were stable and standardized, and the language of the medium was well known. However, as said in the paragraph on flat movies in chapter 1, the real revolution in audiovisual creation is about possibilities: the

tools and technologies recently involved, the switch to new media and the introduction of new professionals in the working pipeline require producers able to discern among the ocean of instruments at the disposal of content creation.
They can surround themselves with knowledgeable people, but they must comprehend the implications of the choices they make for their productions.
That does not mean that a producer needs to have a technical background of the technology or format they are using; however, they can benefit from general knowledge to be able to communicate with all the crew and department members efficiently.

To confirm this, here is NFB's English Interactive Studio Producer David Oppenheim's experience:

"Personally, I like to know as much as I can. So I have taken programming courses, played around and taken courses of Unity, and also made a few things with it.
However, I spend much more of my time doing the equivalent of watching lots of films: I play a lot of VR, and I try different experiences, but I also play 2D flat-screen video games and go to specific live immersive theaters because I think they are all related to VR.
As a producer, I primarily must understand the medium and its affordances; the rest is helpful but not required.
There is a role that comes from software development, the project manager, that often is much more of a technical role.
So I would hire a project manager who knows more about the workflow and the pipeline and can have more in-depth conversations with a game engine programmer or 3D artist than I can.
But even in the role of a project manager, they do not know as much as the 3D artists or the programmer, so they have to rely on some knowledge and being able to ask good questions, communicate and interact with technical figures." [1]

2.2 Director and Creators

A director is a person who determines the creative vision of a feature film, television show, animation product, short film, or other productions. They have complete artistic control of a project.

[1]NFB's English Interactive Studio Producer David Oppenheim. Interview. Conducted by Giuseppe La Manna, May 2022

The director's figure in the animation and flat movie worlds remains similar to this description. However, the new technological tools at their disposal can include some creative benefits.
Especially VP, being the most innovative of the changes, can influence the director's work in different ways:

- Increased agency over the final image: when collaborative elements such as previs are easier to change and quick to render, directors gain more creative input for pre-production. The closer they get to a shared vision that everyone can see and refer to, the more likely the final project will reflect that vision. A real-time engine enables a more iterative workflow to create reference imagery reducing frictions and dead ends. It also means creative alignment during a period when assets are less costly to create and modify, with increased ability to contribute for all department heads.

- In live-action productions, using a live LED wall instead of a static green screen can provide additional benefits such as increased accuracy and control over framing and lighting. It also helps direct actors' performances, who will know what they are looking at and be able to modulate their interpretations to match the action instead of suffering from green-screen fatigue and disorientation.

- The director can have an accurate daily revision after a shooting or an animated sequence production instead of waiting days, weeks, or even months until a final version is ready.

(Kadner. [2019])

Having had the opportunity to investigate inside the Interactive Studios at the NFB, I have noticed how the term director is rarely used while working on interactive and immersive works.
In producing these kinds of content, it is challenging to identify a single person as the director. It might be more accurate and easier to consider a group of people, usually referred to as Creators, who direct the project together instead of a single person in charge of the whole experience.
The reason for this shift concerns the nature of interactive works: an interactive or immersive project involves in its production a user experience design. Not only does this kind of design imply a creative vision, but also a reasonable amount of technical knowledge Considering the triangle system analyzed in the previous chapter, none of the three teams can work without the others. Front-end and back-end production require as much project vision and creativity as the narrative

and visual side of the interactive experience, being the connection point between the story and the user.
For this reason, referring to the heads of the teams as Creators, instead of considering a single director, gives the proper importance to all the work put into the project.
If, for any reason (legal, bureaucratical, financial, ext.), the project needs to define a single director, their work would be to connect and align the different visions of the various teams into one that creates the best interactive or immersive experience.

In terms of union agreements between studios and workers (especially in North America), an audiovisual product not presenting the figure of the director is a huge anomaly. Directors have always been the artistic and creative center of productions, and their rights were among the first ones to be protected in the movie industry.
The challenge for the future of Interactive Studios is to negotiate with trade unions and guilds the terms of the role of Interactive Creators, the division of the rights on their pieces, and the definition of the optimal working conditions for this new category of audiovisual workers.

2.3 Director of Photography

The DOP is responsible for the photographic look of the picture, whether the project is in film or the digital world. They work closely with the director to ensure that the photographic vision aligns with the director's overall vision for the project.

That becomes more challenging on a VFX-intensive project when much of the frame is created long after principal photography wraps. The disorientation and frustration of shooting actors alone on a vast green screen is a familiar scenario in modern filmmaking.
Virtual production can help increase the level of certainty over the final image.
VP can also provide a greater level of collaboration with the art department, production designer, and visual effects team. The efforts of all of these teams have a significant impact on the final image. (Kadner. [2019])

In movie production, the DOP's department faced the introduction of different new figures, especially after the shift to digital equipment:

- The Digital Imaging Technician or DIT is a person who works in the camera department directly under the DOP. In the past, when shooting film, this

role was not needed. The DIT is a highly skilled position, as it deals with the digital workflow of the footage shot on set. This workflow includes backing up the footage onto drives, working with settings on the camera, dealing with signal integrity, and image manipulation when needed. The main goal of the DIT is to achieve the highest-quality image possible from the shot footage. Sometimes the DIT will be able to show the DOP and director what the footage would look like after manipulating the saturation or exposure instead of waiting to see this in post. Another goal of the DIT is to ensure the files are not corrupt and are output in a format that post-production needs. This step is also essential to ensure a smooth post-production.

- Another new position in the camera department due to the advent of digital cinema is the Data Wrangler, sometimes called the digital imaging assistant. This position is basically an assistant to the DIT. On any movie shoot, there are tons of digital files to deal with, so the data wrangler is there to help manage and organize the footage. They manage and transfer the footage to the computer, interact with the camera assistants to ensure all the footage is accounted for, and work with the sound mixer to secure all the digital sound recorded on set.

- Video village on a set means setting up a place to have a monitor for the director that will show what is being shot. This exists on certain shoots based on the budget or the director's preference. Some directors do not mind watching a small monitor attached to the camera. Others want a large monitor set up in another room or outside under a tent.

In Animation and Interactive projects, the role of the DOP became essential, especially when using 3D environments.
In addition to the most obvious themes such as light and framing, their knowledge can be used on camera movement and handheld operating, focus pulling, depth of field, and more in general to all the photographic grammar that is normally associated with live-action.

2.4 Virtual Art Department

The Virtual Art Department or VAD is another area that is part and parcel of virtual production. Think of the VAD as a transitional team bridging the work of a more traditional art department and a regular previs department via the advent of real-time animation.
The VAD's primary role is the development of real-time assets from initial look development to production-ready models and environments. The VAD also assures consistency and high quality across all real-time models. It acts as a liaison

between creatives and artists to ensure all stakeholder feedback gets fully incorporated into the assets.
A traditional art department's work is generally focused on visual development and pre-production. The VAD does not differ in terms of emphasis, yet the main difference lies in the task of delivering complete camera-ready assets for production instead of handing off to set building or visual effects departments.
With this in mind, the work of the VAD may be more involved and intensive compared to a more traditional workflow because it blurs the line between pre-production, production, and post, following all the different phases from the development to the output, handling a larger share of the final imagery. (Kadner. [2019])

2.5 Production Design

Production design is another area of movie creation that has been deeply transformed by virtual production techniques in the form of provisional imagery. Advancements in CAD design have been happening for decades in set design and construction, making pure 2D drafting techniques increasingly rare in production design.
The addition of real-time engine technology supercharges this approach and provides various benefits for the production designer:
Virtual scouting of set designs enables the production designer to view and share a highly realistic simulation of the planned set designs. View sightlines determine if all the desired camera angles will work, and decide "how much of the set" to actually build. This empowers this figure to deliver precisely the set designs needed with much higher accuracy and cost efficiency while also enabling more experimentation during development.
Production design is further transformed via virtual production with real-time LED wall technology to blend foreground sets with digital set extensions seamlessly, enabling the creation of more elaborate set designs than before. This requires close coordination with the virtual art department to determine which portion of the foreground set should be built and where the virtual wall set should begin. (Kadner. [2019])

2.6 Programmers

The term programmers refers to everyone involved in technically implementing an interactive experience or videogame and dealing with the coding part of real-time engines for VP and game development. This includes high and low-level coders,

network and systems engineers, database programmers, computer hardware support, and more.
Programmers are also sometimes referred to as engineers and software developers. Some companies break down the titles according to specific areas of specialization, such as tools programmer, engine programmer, graphics programmer, and database programmer. In general, the programming team's responsibilities include the following:

- Drafting technical specifications;
- Technical implementation of the experience, including structuring data, managing communications, software prototypes, software tools, and game modules and engines;
- Documenting code;
- Coordinating with QA engineers to fix or resolve bugs.

(Adapted from Fullerton [2018])

Coders and programmers are getting more and more involved in the production of audiovisual works. As mentioned before, they work with real-time engines for virtual production or interactive experiences; however, when working with VFX or animation, they can deal with particular tasks, such as creating unusual shaders or particular physical simulations.

2.7 Technical Director

Technical directors (TDs) are generally responsible for technical processes and equipment in software and industrial companies, theaters, or TV studios. Technical directors are particularly important in film and game development, especially in productions involving animation and visual effects.
Typically, they are a combination of an artist and a programmer, responsible for the more technical aspects of film production, such as programming shaders, developing rigs and animation setups, performing complex simulation tasks, and setting up the pipeline.
Therefore, artistic skills are required in addition to extensive technical skills. TDs in the film and games sector often have a background in mathematics, physics, computer science, or media informatics. They are proficient in common programming languages, and at the same time, they should know about the uses of image and video editing software, 3D modeling and animation, and game engines and be able to apply them creatively. (Animationinstitut [2021])

I have found an interesting definition of the role of the TD during the interview with Eloi Champagne, NFB English Animation & Interactive Studio's Technical Director: he often describes his job's tasks as "*finding technical solutions to creative problems, and creative solutions to technical problems.*"

"Everything is around technology. It is all about making sure that we have the best tools to translate the creators' vision. That could mean creating shaders in Blender to make the vision happen and get the look we need or building the projection dome for an immersive experience.
But it also sometimes means taking what the Creator has in mind, and even though the technology is not quite there, finding a creative way to use tools that are not intended for that particular purpose but employing them differently to obtain the desired result.
To be honest, I consider this, one of the pleasures of my job."[2]

At the NFB's Studios, I had the feeling that all the departments and productions rely a lot on the job of the Technical Director. When working with all the possibilities that digital and virtual technology offer, TDs are considered the focal point in discerning and implementing the right tools for a project, putting much pressure on the role.
At the speed technology is evolving, it seems impossible to be able to keep track of all the advancements; however, a TD has to be prepared and updated to face every production need, making it, in my personal opinion, the most challenging role in the modern audiovisual production process.

2.8 Research and Development

In the previous chapter, we analyzed how the creation of the Cinema Industry led to developments in technologies and techniques.
Most of the production Studios invested in creating Research and Development (R&D) departments to investigate and explore the opportunities coming from new tools and instruments.
The examples of inventions coming from the "laboratories" of the studios are numerous, for example Disney's Multiplane Camera or NFB's Sprocketape.

With the introduction of the digital world, the R&D work moved towards an

[2]NFB's English Animation & Interactive Studio Technical Director: Eloi Champagne. Interview. Conducted by Giuseppe La Manna, April 2022

IT direction, mainly developing hardware and software for their productions.
Studios like Sony Pictures or Disney started to invest considerable resources into developing proprietary technology. They protect intellectual property through various methods, including non-disclosure agreements, patents, litigation, and security.
This logic sees media companies like Walt Disney operating through research institutions such as Disney Research, a private R&D lab that funds postdoctoral and tenure-track researchers' work. (Adapted from Gowanlock [2021])

In the case of smaller studios and public institutions, the capital available for R&D cannot compete with Hollywood's majors.
However, there never was the need for them to develop proprietary instruments thanks to the democratization of digital tools developed by private software companies and sold via subscription or perpetual license, or even free-to-use (I.e., the Adobe Suite, Blender, Toon Boom, Drangonframe, Unreal Engine, etc.).
For this reason, their research has moved to other fields.
Due to the introduction of digital formats, R&D in smaller studios worked a lot in defining export standards and deliverables, usually working between the end of production and the beginning of distribution.
R&D departments have also invested in the Studio's works' preservation, conservation, and accessibility. With the digitalization of the industry, preserving past productions has become more and more important (more in chapter 5).
For example, one of the last NFB's technological plans invested on the digitization of NFB's collection and its preservation, for which they have developed the Vault for the archives, the pipeline for the digitalization of film, and the web catalog nfb.ca.

According to NFB's R&D & Digital Platforms Director Jimmy Fourier, the future of R&D holds more integration of their research work in the production process.
Since the intensive use of technologies is changing the workflows, R&D should intervene with technical approval before switching to production.
The technical approval allows providing the production crew with documentation on the technology and its impact on the project pipeline, so that they can always work with compatible assets and external resources[3].

[3]NFB's R&D & Digital Platforms Director: Jimmy Fourier. Interview. Conducted by Giuseppe La Manna, April 2022

Part III

Distribution and Festivals

Chapter 3

Distribution practices

3.1 The distribution of flat works

The distribution of audiovisual works is an issue that has been largely discussed in the past years, especially after the introduction of the new streaming platforms.

In the early cinema industry, the concept of distribution was fairly straightforward, although the logistic of this process was not always easy. One of the main challenges that needed to be faced was sending a limited amount of film copies to movie theaters in different areas. Bigger cities or populated zones would receive more copies, sometimes even more than one per theater, to cover a higher demand, while in rural areas, where the public was smaller, the copies could be shared among different theaters. The second challenge concerned the film support, which was very delicate and likely to be damaged and scratched after numerous projections.

The television era signed an essential change in the distribution of movies. Until that moment after their theatrical release, films exhausted their monetary gains; however, thanks to television, they could be broadcasted after their theatrical release and continue to monetize thanks to distribution rights.

In the early '80s, the cinema industry developed a distribution business model in order to avoid conflicts with the new VHS home video, pay-per-view, pay-TV, or broadcast television.
The model is called the *release windows system* and consists in dividing the distribution for different formats in time windows.
Originally, a movie was first released through movie theaters (theatrical window); after approximately six months, it could be released to home video (such as DVD

or VHS) and video-on-demand services, entering the video window. After an additional number of months, it was usually released to pay television, and approximately two years after its theatrical release date, it was made available for free-to-air television. (Epstein [2005])
Sometimes, the theatrical window could be preceded by a festival window: film festivals usually require the works not to have been distributed on other platforms to be eligible for submission (more in the next chapter).

Digitization has radically changed the way we consume films outside cinemas. Smartphones, tablets, improved internet infrastructure, and other technological developments allow watching films everywhere, expanding our understanding of home video and covering film consumption anywhere. (Gaustad [2019])
The introduction of streaming services has directly influenced the classical distribution system in a way that previous forms of home video had not. Studios increasingly realized that shorter theatrical windows lead to more significant profits for SVOD (Streaming video-on-demand).
The COVID-19 pandemic largely influenced the distribution market and signed important turning points for future decisions: in 2020 theatrical global box office market was down 72% over 2019, with an income difference of over USD$30 billion. However, SVOD was essential for the Movie Industry because during an otherwise punishing year for theatrical exhibition, home and curated entertainment boomed, allowing the total global theatrical plus home ente rtainment distribution market to lose only 18% of revenues compared to 2019. (Figure 3.1)
2021 marked the onset of the industry's rapid rebound. The combined global theatrical and home/mobile entertainment market reached $99.7 billion, a growth of 24 percent since 2020, but more importantly, surpassing the pre-pandemic 2019 value. (Data from Motion Picture Association - Theme Report 2021 - MPA [2021])

SVOD is proving itself a powerful tool for distribution; however, it has been the target of different discussions in the film industry:
On one side, there are the studios and the streaming companies who claim that the shift gives "*access to people who cannot always afford it or live in towns without theaters; letting everyone, everywhere enjoy releases at the same time, and giving filmmakers more ways to share art.*" (Netflix Twitt, May 4th, 2019); while on the other side cinema owners and film festivals still resist, arguing that it would "*put hundreds of cinemas at risk, along with the jobs and local services they support, leading to less rather than more film choices for the public.*" (UK Cinema Association about release windows).

Looking closer at the current situation of streaming services, it can be noticed how they are still trying to comprehend how to manage the right balance between

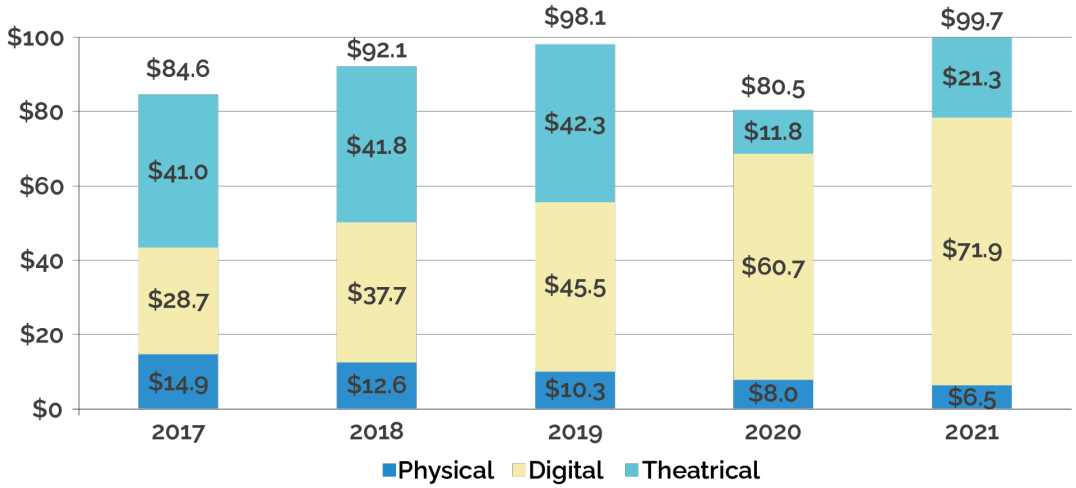

Figure 3.1. Global Theatrical & Home/Mobile Entertainment Market (US$ Billions) - Source: Omdia (International), Comscore - Box Office Essentials (Theatrical), Digital Entertainment Group (U.S.).

theater release and on-demand.
During the first years of post-pandemic, for example, Disney tried different mixed-release tactics: *Jungle Cruise*[1], *Cruella*[2], and *Black Widow*[3] had simultaneous theatrical and Disney+ releases as Premiere titles, using a Vip overcharge, while a few months later, titles like *Shang-Chi*[4] or *Doctor Strange in the M.o.M.* returned to a post-theatrical VOD release, though with a much shorter in-between windows time. (White [2021])

The simultaneous release, also called the Day-and-Date release, did not prove itself a valid alternative for streaming platforms or movie theaters. As reported by John Fithian, head of the National Association of Theater Owners, during 2022 Cinemacon, this business model was killed by piracy.
In fact, according to TorrentFreak, Black Widow was the most pirated movie worldwide for three consecutive weeks after its release, while high resolution copies of Jungle Cruise proliferated across the internet just hours after its digital premiere. The streaming release gives pirates the possibility to share movies or series at their

[1]Jungle Cruise (2021) - Directed by Jaume Collet-Serra - Disney Production

[2]Cruella (2021) - Directed by Craig Gillespie - Disney Production

[3]Black Widow (2021) - Directed by Cate Shortland - Marvel Studio Production

[4]Shang-Chi and The Legend of The Ten Rings (2021) - Directed by Destin Daniel Cretton - Marvel Studio Production

maximum audio and video resolution after only a few hours from the digital release, killing a large part of the market and losing incomes from both the theatrical and the SVOD windows. (Watson-Schwartzel [2021])
A 45 days exclusive theatrical window, however, would be a fair compromise between theaters and streaming platforms. According to 2019 Cumulative Box Office Revenues from Box Office Mojo (pre-pandemic data for in-theater box office market are more reliable compared to the pandemic and post-pandemic ones); 90% of box office revenues are captured within two months after theater release. Therefore, releasing movies in streaming services sooner on average, would better serve the market without hurting theater revenues.
As shown in the below graph, 45 days of theatrical window (almost six and a half weeks) would guarantee theaters more than 80% of their expected income while allowing streaming platforms to benefit from an early SVOD release. (Granados [2021])

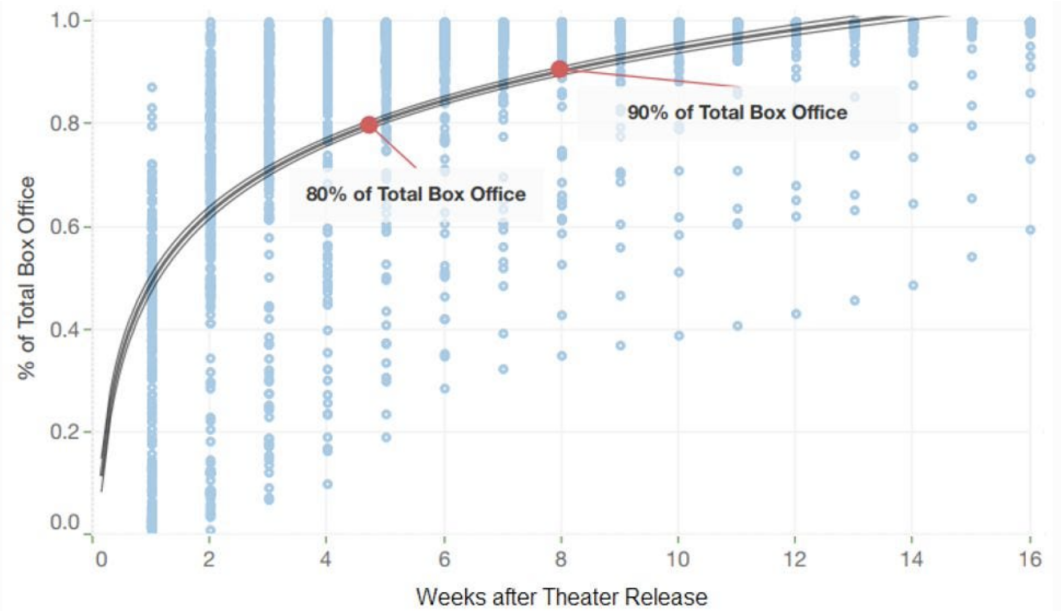

Figure 3.2. 2019 U.S. Cumulative Box Office Revenues + Trendline based on a logarithmic regression. Data points are for 207 movies released in the U.S. in 2019. Pepperdine Institute Data Source: 207 movies from 2019 in Box Office Mojo - Forbes 2021

If, in the past, independent projects or small productions were obliged to limit their access to the public due to the elevated costs of theatrical distribution, today, they have many more opportunities to share their creations. Furthermore, streaming companies have started to develop and invest in their own productions, becoming full-fledged production studios and increasing the possibilities for creators and

artists to see their ideas not only presented to the public but also financed.
However, streaming platforms are not very transparent about their viewing data. This might not be relevant for their business model, but it prevents creators and production studios from having a complete insight and perspective about works' actual success. Moreover, the algorithms that the streaming platforms usually implement tend to bury certain titles giving ephemeral notoriety to the majority of the productions. This can affect the future investment decisions of streaming companies' next productions since many of those are made around big data obtained from the users rather than from an actual desire to finance diverse, edgy, new, and auteur-driven projects. (Izquierdo [2018])

On the counterpart, movie theaters are adopting a series of strategies to maintain their appeal to a large public and avoid succumbing to the growth of SVOD. On this specific topic, cinemas are reacting with the same strategy they used in the past when the first home video solutions became more and more popular in the '80s. They focus on enhancing the in-theater movie experience using premium large-format (PLF) auditoriums.
PLFs are auditoriums where best-in-class image and sound technology features prominently and sometimes include newer formats, like immersive seating and panoramic screens, often combining different elements.
Among the already well-known formats and technologies used for PLFs, such as IMAX, Dolby Atmos, or UltraAVX, some of the newer cinema experiences involve Ice Theater which incorporates LED panels siding the screen, adding peripheral background elements to the viewer's line of sight or D-Box which uses motion seating system in harmony with the sound and visuals on-screen. (Loria [2021])

How are those trends influencing the production?
Distribution and marketing departments are usually already consulted during the development and production phases.
The choices of the distribution platform and format are usually taken by producers but, today more than ever, early involvement of the distribution department is essential to be able to develop the best strategies and placement for the product.

It is unlikely that streaming distribution will kill the theatrical experience because theater projections still maintain their fascination and appeal to a large slice of the public, thanks to the enhanced formats that are impossible to replicate on-demand.
Nevertheless, on-demand and streaming services are indeed the most important and influential distribution formats, and they can only grow in the future.
It is essential for people involved in this process, from distributors to theater owners, to find a way to balance distribution formats, because this would make it

possible to gain the main advantages from both practices simultaneously.

3.2 The distribution of Interactive products

3.2.1 Web-based experiences distribution

Compared to the distribution of more classical formats, interactive and immersive works face more challenges.

For web-based interactive experiences, the distribution format has always been integrated into the very nature of the product: the internet is both the platform in which the project sits and grows and the distribution/sharing means that enables access to people. Web browsers were the first platforms that hosted those kinds of works thanks to Flash, as mentioned above.
Today, browsers are not the only sharing platforms for those experiences anymore; most of the time, they can be designed to be suitable for mobile devices in the form of apps downloadable from app stores.
Compared to only using browsers, working with apps makes the production process more complicated: first of all, the sharing platform should already be defined from the experience's concept phase because it influences the coding and design choices accordingly to the device they run on.
Second, mobile application distribution is not a straightforward process; in fact, app distribution channels can be very strict with publication rules.
The Apple App Store, for example, has the most restrictive mobile app distribution process, to be able to protect Apple users from malware and guarantee higher compatibility with system upgrades. What makes publishing through the App Store challenging is the requirement of the provisioning profile, which contains app information and entitlements (a right or privilege that grants an executable particular capabilities), specifying the system resources an app can use.
By contrast, Google Play, which works with Android apps, is much less restrictive; of course, there are some technical and legal restrictions and requirements, but generally speaking they do not cause significant troubles.
While enterprise app catalogs such as those available through Blackberry UEM and Microsoft Intune may be less restrictive but they each have unique requirements. (Khaleeli [2021])
Those differences can sometimes lead to avoiding publication on more challenging channels, but since the distribution goal is to reach the largest number of people possible, leaving significant market branches out of the distribution circuit, like Apple users, can affect the product's visibility.

For web-based and app interactive experiences, the biggest challenge is not accessibility, but rather public awareness, which can be tough to be reached for those kinds of works. That is why awareness marketing campaigns are essential.
App stores usually promote the more downloaded applications on their home pages, while browsers do not really have a website recommendation list. The marketing departments of interactive studios meet the challenge of finding the public and targets for their productions and suggesting the best way to access them. The marketing campaigns depend on the nature of the experience and should usually be created in collaboration with the creators: QR codes, external links, transmedial formats, and social networks are the most common and easy-to-use access formats.
Some studios, which have a large production of interactive experiences, can also use an archive website (I.e., nfb.ca) to guarantee access to their works, even after the end of the marketing campaign; however, this solution is usually only for a niche public already aware of the studio productions.

3.2.2 VR/AR/XR distribution

The distribution of immersive and interactive VR/AR/XR works is quite different from the previous ones.

Those projects are highly hardware-dependent, and the tools needed to access them are still not popular among the public.
However, distribution platforms such as Steam and Oculus are the main sharing formats for VR experiences to be accessible from home via HMDs.

The Oculus and Steam distribution platforms are mainly gaming-centered, meaning that more experimental narrative pieces have traditionally not been welcomed or well-received on these platforms.
However, Oculus is trying to create an area inside its ecosystem dedicated to enjoying and sharing the best immersive narrative experiences.
Facebook hopes to make Oculus TV the primary downloadable immersive story applications portal.
Oculus TV originally streamed 360 videos, but it now features sections of Critically Acclaimed Free Downloads and Premium Downloadable Experiences that link to the store pages for immersive story apps.
This is a step towards co-locating storytelling, so the experiences do not have to compete alongside premium gaming content.
However, the term “TV” in the app’s title does not immediately invoke an image of premium interactive stories. These stories are also rated using the same Oculus

store backend as other Apps & Games, making them susceptible to review bombing from gamers.

As we have seen for mobile applications, working with external distribution platforms can expose to sharing restrictions. Independent VR game developers or smaller studios who cannot secure official distribution on the Oculus store have turned to sideloading content for the Quest using SideQuest. Nevertheless, SideQuest still primarily targets gaming community members looking for more innovative and experimental gameplay mechanics, and immersive narratives can easily get lost in it. (Bye [2020])

To increase the accessibility of those works, creators and distributors choose to share the experience on multiple platforms. This choice is very common, yet experiencing a VR work on a bi-dimensional screen, such as a desktop or a mobile phone, can affect the power of 360° immersion.
XR and AR, however, find in mobile devices extremely performant tools: gyroscopes, lidar sensors, HD cameras, and the high computing power of new smartphones and tablets are enabling easier access to those kinds of works, thanks also to the prosumer applications that mobile and online stores are promoting (I.e., Apple's ARKit or Google's ARCore).

The innovative and noncommon nature of those experiences, as well as the focus on gaming of the sharing platforms, frequently forced distributors to share their works at a meager price, or even for free, to be able to compete with other kinds of productions. There has been either nominal or negligible compensation for those products, which has not made it a viable business venture for many independent producers, and overall the market seems to be still in too early of a stage to support a diverse ecosystem for storytelling VR creators. (Bye [2020])

Because the dominant existing distribution channels are primarily focused on gaming, and due to the costly VR hardware for the average consumer, artists creating immersive art and interactive stories have turned to the film festival circuit and location-based installations at museums, art galleries, libraries, and cultural centers to let the public access their content.

Location-Based Virtual Reality (LBVR) is a promising consumer gateway to VR. It is becoming increasingly common for people to be first introduced to an immersive experience through installation setups and also for users to return to these locations for more.
Taking advantage of the consumer technology and distribution channel gap, LBVR is somewhat akin to cyber cafes, museums, and cultural centers, as it provides users

with a VR headset and a custom-designed space to freely experience in VR.
Demonstrating the immersive potential of VR in this way is viewed as a potent means of increasing VR awareness (and therefore uptake) amongst consumers. (Bonasio [2019])

The similarities between this VR distribution model and the very early distribution of Cinema might appear uncanny. At the beginning of the 20th century, when theaters were not so common, some countries employed traveling projectionists who would go from region to region to show films to those who did not have the opportunity to go to a cinema, bringing with them all the technological equipment needed for the projection.
What VR is living now is pretty much the same: it is a new medium, still trying to define its grammar and storytelling rules, and it is hard to access for most people, for the reasons explained above; so to be able to connect with them, it travels from museums to galleries, from cybercafes to festivals.

Chapter 4

Festivals

Last but not least, this section will focus on audiovisual festivals.
In Cinema history, festivals have always represented important events for particularly creative and artistic productions, giving those works much more visibility and focusing the public's awareness on their value.
Festivals can be internationally and worldwide known, like the Big Five (Venice, Cannes, Berlin, Sundance, and Toronto), or can address a national public or even local audiences. Certain festivals target specific communities or demographic groups; good examples are LGBT and queer film festivals, women's film festivals, and festivals aiming at particular ethnic communities. This category of events can also be referred to as identity-based festivals because the thematic selection of films programmed for these is made with an explicit interest in engaging identity questions and representational issues that concern specific communities and groups.

Besides general events, which screen all types of film, many festivals choose to focus on one genre. Such specialized or thematic events may span the complete spectrum of high-to low-brow culture; cover niche, cross-over, and mainstream tastes; and cater to professionals as well as the general public. In addition, well-developed sub-circuits are focusing on popular genres like horror, fantasy, and sci-fi, but also niche fests for silent and archival film. Other genre-based film festivals include documentaries, animation, short films, experimental cinema, and student films.
Even if the classic festival settings continue to dominate, a new generation of film festivals is dawning: festivals that take place online, focus on films shot with mobile phones or tablets, and experiment with interaction and virtual reality. (deValck Kredell-Loist [2016])

Since the first one (Venice 1932), Film Festivals have been an important instrument, giving filmmakers, distributors, critics, and other interested people opportunities to attend showings and meet to discuss current artistic developments in film. Moreover, at festivals, distributors can purchase films they think can be marketed successfully in their own countries.

Figure 4.1. Venice Film Festival red carpet - John Rasimus/STAR MAX/IPx Picture.

The connection between festivals and distribution has always been tight; in fact, part of them require the movie not to have been shared with the public to be allowed to participate in the festival selection.
These requirements can sometimes be a limit for some productions which would preferer to reach the open public earlier, but at the same time, they want to take advantage of the importance and visibility that festivals confer.
In the past years, some festivals - Cannes among all - opened a significant debate about the new forms of distribution, like streaming and online sharing, and did not accept some streaming platforms' works without a theatrical release to protect the rights of theater owners.
On the other side, companies like Netflix only release productions in theaters when and if they think they have the chance to be nominated for an Oscar or other prizes. This practice, of course, is frowned upon by theater owners, who, in the past, have refused to show those movies in their cinemas.

As already mentioned, this issue is still ongoing, but since the distribution practices of the industry are changing, the only solution for the future of film festivals and productions is to find a balance between theatrical and on-demand access.

The democratization of videomaking tools, connected to the digitalization of cinema, has drastically changed the festival environment.
Today, more and more people can produce good quality works: even a one-person production with a meager budget can do well in some important festivals. For this reason, festivals receive today a much larger number of submissions compared to the past. Consequently, the need for creators to show their works has grown, leading to an increasing number of Film Festivals worldwide.
The diversification in genre-based festivals is a direct consequence of this, allowing filmmakers to direct their works to the public they created them for.
In 2016, for the first time in its history, Venice Film Festival introduced the Venice VR Expanded section in its program: this was a crucial moment for Interactive and Immersing productions that started to acquire more and more importance in the festival circuit. Today, most of the Big Five and many other festivals have an Interactive and Immersive section or are even totally dedicated to it.
Along with LBVR in the museum and cultural centers, VR Festivals have represented the most successful way to promote and give the public access to interactive experiences.

The film festival circuit is an opportunity for immersive artists to experiment and explore the storytelling potential of emerging technology devices like haptic devices, experiments with smell and taste, immersive theater productions, multiplayer social experiences, all things that are impossible to experience at home because they go beyond the technologies the average VR consumer can access.
The film festival circuit has been able to cultivate an audience for immersive storytelling that includes funders, curators, creators, and some nascent press attention. The funding cycles for these works largely revolve around premiering at one of the major festivals on the circuit. (Bye [2020])
However, the VR festival environment seems to have created a niche, involving only those who work in the field or already know it.

The challenge for VR festivals in the near future is to increase their mediatic coverage and try to direct people's awareness into the works they promote each year. Despite the repercussions for most sectors, the pandemic helped to find an alternative way to increase people's attention to the VR festivals: 2020 Tribeca Immersive was the first film festival to explore new virtual distribution using Oculus TV as the main streaming platform. Official festival data said there were over 46,000 total streams of the program, which is exponentially higher than the people

they would have been able to serve at the in-person festival because, across ten days, only 4000 users would have been able to try the experiences.
Mixing in-presence and virtual distribution can help VR festivals gain more visibility and promote the VR works to a larger public.

Part IV

Legacy

Chapter 5

Audiovisual Legacy

After discussing the production process of audiovisual production, the professionals involved in this process, and how the final product is presented to the public, the next step is to analyze what the end of production leaves behind.

The Legacy of an audiovisual work can be seen in different ways: its cultural heritage for future generations, the physical or digital products of the production process, or even the memory of an experience that made us feel a certain way.

5.1 Preservation, conservation, and access

In most modern societies, Cultural Heritage is a well-established and affirmed concept. Most countries have ministries, institutions, or collectives whose task is to preserve and take care of their artistic and cultural Legacy.
Unesco defines the Cultural Heritage of a country as:

"...in its broadest sense, both a product and a process, which provides societies with a wealth of resources that are inherited from the past, created in the present and bestowed for the benefit of future generations.
...
Cultural heritage holds the potential of promoting access to and enjoyment of cultural diversity. It can also enrich social capital by shaping an individual and collective sense of belonging, which helps supporting social and territorial cohesion." (Unesco [2014])

This definition also includes the Audiovisual productions and, more in general, every kind of story and narrative.

When discussing the preservation and conservation of Cultural Heritage and Art, we are used to thinking about architecture, paintings, drawings, prints, sculptures, and decorative arts objects because of their physical and tangible nature.
However, most of Cinema history was connected to a physical and tangible support that, by nature, lasts and decomposes at an alarming rate when neglected.
Early cinema was considered a commercial asset with little to no cultural value. Once a film was removed from theater circulation and exhausted its monetary gains, the early cinema industry did not find any reason to keep or protect it for further use. Because of such treatment, preservationists and restorers are often left with the task of filling in the blanks to the best of their abilities. (Bastron [2013])

Nowadays, however, we recognize the importance of audiovisual productions and how they affect our culture.
The first challenge for cinema archivists and for the institution they work for regards the conservation and preservation of cinema's physical support: the film.
Conservation and preservation are two approaches that focus on the physical state of a film element. While conservation can involve repairs or chemical treatments, preservation applies peripheral actions that minimize deterioration and prevent new damage to the film object — actions like environmental controls, deterring pests, and creating access copies to minimize handling of the original elements. (Shields [2020])
Institutions and even Studios have invested capital in preserving and protecting their productions; some examples worldwide are the Walt Disney Archives, the Cineteca di Bologna, the NFB's Vault, or the BFI National Archive.

Figure 5.1. Inside the NFB Vault - NFB Blog.

In the context of cultural heritage, preserving and conserving are not enough; what makes this process legacy is the possibility to access the preserved material.
However, film is a delicate format and sometimes its safekeeping challenges accessibility. To protect their collection and discourage access, some archives, such as Britain's National Film and Television Archive, require a small fee from students, researchers, and historians. (Bastron [2013])

The digital era and the expansion of the internet allowed to formulate a solution to this problem:
Cultural heritage institutions such as archives, galleries, libraries, and museums have invested resources both in digitizing their assets and in technology aimed at increasing public access, such as digital multimedia platforms, including social media.
Simultaneously, digital tools led to the production of digital-born contents, ready to be shared and archived in formats and supports not affected by deterioration or degradation. (de Vijver [2016])

In 2007 a Hollywood Reporter review of AMPAS[1], *The Digital Dilemma: Strategic Issues in Archiving and Accessing Digital Motion Picture Materials* (Giardina [2007]), identified instances where digital content could not be accessed after only 18 months.
Since then, however, technological advancements have mitigated this problem.
The introduction of more stable and distributed infrastructures to store the digital version of audiovisual content guaranteed more safety and, at the same time, less risk of obsolescence compared to the initial use of physical supports such as DVDs and Blue-Rays.
Today the main issue concerning digital storage of audiovisual works involves allocating digital resources to store them and the costs of maintenance of those infrastructures; however, compared to the physical space and conditions that film storage and conservation implicate, the advantages are definitely more than the disadvantages.

Not all kinds of Art can be accessible, stored, or preserved for future generations. Some Art forms have a lifetime composed of single and unrepeatable moments since they are connected to a performance or a personal experience.
Examples are theatrical plays, music concerts, dance shows, or artistic performances, which can be experienced multiple times, but each repetition will not be the same as the previous one.

[1] Academy of Motion Picture Arts and Sciences

In the audiovisual world, something similar, but not identical, can be seen with interactive and immersive works.
We have already analyzed the concept of End-of-Life for interactive projects and how access to those is impossible for the public after a limited amount of time.
The software and hardware of those works would need to be updated constantly to be able to perform in newer and newer machines. An idealistic solution would be to "hibernate" the used technology, which is impossible if the experience needs access to external resources such as deprecated API or databases.
Another similarity with other Art forms is the concept of experience itself: each person experiences the interactive or immersive work differently and uniquely compared to others. Even if recorded, transcribed, or reported, an interactive experience would lose its narrative and emotional power, which resided in the personal experience.
Those characteristics make preserving and conserving interactive projects difficult, if not impossible.

5.2 Documentation and maintenance

When working on Interactive works or projects involving a good amount of coding and programming, drafting legacy documentation can be a good practice to adopt from software development.

The codes need to be reviewed, tested, and re-designed; changes, bugs resolution, or adaptation for other platforms may occur even after the production phase.
Projects with a long post-release phase may face the departure of the developers who worked on the original version, leaving the maintenance and updating tasks to new ones.
All the considerations above highlight the need to document the code of the experience, leaving a legacy to the people who will take care of it until the End-of-Life.

In previous chapters, we have seen how the interactive project's creative vision is shared between teams that work simultaneously on different tasks and parts of the experience.
To coordinate a shared vision among all the professionals involved in a project, the Game Industry uses design documentation, whose purpose is to communicate the project vision in sufficient detail to implement it.

Documentation means different things to different members of the team. To a producer, it is the main instrument to keep track of the production of the whole project. The producer must approve the documentation and its vision before it is shared among the developers. To a designer, it is a way of fleshing out the producer's vision and providing specific details on how the experience will function. The head of the creative team or the lead designer is the documentation's principal author, except for the technical specification, which is written by the senior programmer or technical director.
To a programmer and artist, the documentation is a series of instructions for implementation and a way to express their expertise in formalizing the design and list of art and coding tasks. (Ryan [1999])

Film Production also uses documentation during the making process of a movie or an animated product: it helps the producer, the crew, and actors to keep track of the workload and tasks.
However, for Interactive and Immersive production, it assumes the connotation of a legacy to pass to the teams that will work on the maintenance of the experience during its life cycle.
Moreover, a well-written design and code documentation, along with the codes and the assets of the experience, can be the only means of preserving and conserving

interactive works and games, leaving the possibility for future remastering.

Part V

Conclusion

Chapter 6

Final Considerations

This thesis aimed to identify how the production processes and standards of audiovisual works have changed due to the influence of new technological possibilities. Based on the research period at the National Film Board of Canada, the helpful knowledge of the experienced people who volunteered to take part in this project through their interviews, and the addition of bibliographical resources, it was possible to determine the current state of audiovisual content creation, and to draw the following conclusions.
The key words that can best summarize the current state of audiovisual production are **real-time** and **iteration**.

Real-time, of course, refers to the increasing role of real-time engines in production. Virtual production for flat and animated pieces allows the creators to solve most of the uncertainty problems caused by the green screen's lack of on-set visual feedback and allows working with ready-to-use and cross-compatible assets from the early production steps.
For immersive and interactive works, the very concept of experience is inbuilt into a real-time logic: the user interaction with the narrative requires real-time feedback from the virtual world or the responsive environment.
Iteration is a direct consequence of real-time workflow: the possibility of receiving immediate feedback allows creators to easily go back to previous production phases to obtain the best results.
Moreover, it opens the possibility in audiovisual production to shift from a waterfall pipeline to an Agile workflow, which, with iteration cycles, breaks product development work into small increments that minimize the amount of up-front planning and design.

With the current state of the production process in mind, we can now hypothesize the future of audiovisual creation and try to understand which factors will

change the production practices.

Which new words will transform and upgrade audiovisual production in the future?

6.1 Democratization

Democratizing content creation is a well-known concept in the audiovisual environment. I used it in this very thesis to express how new technologies have given more and more people the opportunity to tell their stories and produce their own content.
In this particular case, it refers to the possibility for creators to use content creation software and tools for free or at a minimal price and pay a percentage of royalty only on the published works.
To understand why this is important for audiovisual production, I would like to use the Unreal Engine example.
The first-generation Unreal Engine was developed by Tim Sweeney, founder of Epic Games, at the end of the last century. After years of game development and four engine generations, in 2014, Epic Games decided to make Unreal Engine 4 available to everyone by subscription for USD$19 per month, plus 5% of all gross revenues of the project. Up until Unreal Engine 3, Epic's licensing costs were high, starting at USD$99 for its Unreal Development Kit but they would also increase for custom licenses.
Different market reasons brought to this decision, including the increasing pressure from the rival Unity, which had already moved from a purchase model to a subscription one.
However, this model resulted in Unreal Engine 4 userbase growing ten times larger in a single year, so at that point, in 2015, the company decided to make UE4 available for free. Today UE4 is free to download and comes fully loaded and production-ready with every feature and full source code access included.
Under the standard EULA, it is free to use for learning and for developing internal projects. It also enables creators to distribute commercial projects without paying any fees to Epic Games, including custom projects delivered to clients, linear content such as films and television shows, and any product that earns no revenue or whose revenue falls below the royalty threshold.
However, a 5% royalty is due only when distributing an off-the-shelf product that incorporates Unreal Engine code (such as a game) and when the lifetime gross revenue from that product exceeds USD$1 million (so the first $1 million remains royalty-exempt). (Games [2022])

UE4 developers have understood how making a profit from users' content creation is more fruitful than asking them to purchase the software, establishing an uncommon connection between Epic Games and their users; as Sweeney pointed out during his intervention at GDC 2019, "*Epic only succeeds when you, as a developer, succeed.*"
As previous chapters have clearly shown, Unreal Engine seems to have accomplished the success Sweeney was talking about; UE4 is the de facto standard of virtual production and among the first game engines used for videogames and interactive experiences development.

What the future of content creation will probably bring is similar to what Epic Games did and is doing with Unreal: software's focus will move from the idea of "*how to get creators to use and purchase the software*" to "*how to give creators the best tools for their creative process and use it to grow together.*"

6.2 Open Ecosystem

If the content creation software market changes its focus on giving tools and possibilities to creators, keeping a closed proprietary software ecosystem cannot be an option anymore. A closed ecosystem refers to a platform or software that only interacts with tools compatible with that platform.
Compatibility between different platforms has always been a big issue in digital content creation. Most software companies provided the integration of as many tools as possible on their platform as the only solution.
However, professional creators want to use the instrument that guarantees them the best result for their work: in a very simple 3D pipeline, for example, this can mean working with Blender or Maya for modeling, with Substance's tools for textures, with Houdini for simulations, and finally using an external render engine to get the final output.

An open ecosystem freely supports and encourages integrations with other technologies and services, allowing scalable and easy data exchange between different platforms.
The tool that will probably be used intensively for 3D is Pixar's Universal Scene Description or USD. USD is an open source software (once again, the concept of democratization occurs) that "*addresses the need to robustly and scalably interchange and augment arbitrary 3D scenes that may be composed of many elemental assets.*" (Studios [2021])
At a file format level, it stipulates how data is encoded and organized for a 3D environment in a much more scalable and non-destructive way compared to current

scene description formats (I.e., .fbx or .obj).
What makes USD a powerful tool is its increasing adoption by most of the professional 3D software in the market, such as Maya, Blender, Substance, and Unreal Engine, allowing creators to switch easily from one software to another.
Cross-platform data exchange allows them to choose from time to time the most suitable tool for their current work and reduces possible production pipeline bottlenecks, maximizing artistic iteration and minimizing latency.

6.3 Collaboration

In a big production pipeline, where different departments and artists work iteratively on the same asset, an interchange tool such as USD is the only way to work simultaneously and collaboratively.
USD's composition arc facilitates multiple artists to work together on the same asset by allowing each artist to operate on their own file (called a Layer), all of which will be combined to build the 3D scene. It makes possible for each of them to work independently without erasing or editing any other colleague's work and helps to provide a clear audit trail of changes that aids in addressing issues (like the changing-topology problem), bringing to full potential the collaboration features that the iterative agile workflow promises.

At this point, the next improvement step for interchange tools concerns the real-time visualization of the simultaneous work of different creators.
One of the first platforms to implement such a feature is Nvidia Omniverse, which is actually built on top of USD technology.
With the Omniverse Connectors, users can connect their digital content creation apps to Omniverse Apps, enabling real-time data and tool sharing between them, eliminating the need for export-import of project data.
Moreover, users can take advantage of Omniverse live-sync capabilities to collaborate in real-time with other team members using multiple apps and from anywhere on the globe.

Making longer term predictions about the future of audiovisual production is hard, if not impossible. Technology is changing too fast and, from one day to another, a new revolutionary tool can come up with a new feature that totally modifies what has been discussed until now.
However, what always needs to be taken into consideration is that all these platforms, pipelines, and standards are just mere instruments in the hands of creators, artists, and producers. The focus of audiovisual arts has to be on creativity, narratives, and emotions as any other form of art.
This is why I like to consider these tools as new forms of paint brushes or sculpting chisels that will enable artists to create the digital and virtual equivalent of masterpieces such as Michelangelo's *Pietà* or Van Gogh's *Starry Night*.

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