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Filip Gabriel Pudło https://orcid.org/0000-0002-1415-1964
Łódź Film School

Małgorzata Kotlińska https://orcid.org/0000-0003-4160-7362
University of Łódź

Wojciech Olchowski https://orcid.org/0000-0002-3731-6485
Łódź Film School

Katarzyna Kopeć https://orcid.org/0000-0002-2426-0275
Jagiellonian University

Marta Materska-Samek https://orcid.org/0000-0002-4432-0933
Jagiellonian University

XR WORKFLOWS IN FILM PRODUCTION: DEMONSTRATION FOR EDUCATIONAL PURPOSES*

Abstract

The use of the XR production technologies has expanded recently in the film industry and heavily influenced the film production process. This paper aims therefore to explore the differences between diverse XR production workflows. The analysis provides criteria for workflow paths of traditional approach to film production and XR production flow, including workflow structure, skills, education, and equipment. Defined XR techniques are discussed for educational purposes. Its illustrations are three case studies of cinematic VR production, computer-generated VR production and Virtual Production. They are the basis for workflow comparison and discussion on artistic decisions and production challenges for film related Higher Education Institutions (HEI) students and scholars.

Keywords: XR, VR, AR, MR, virtuality, virtual production, virtual scenography, production workflow, film production, education, management

JEL: I23, L82, O32, O33

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Introduction

The subject of virtuality is now increasingly becoming actively used in many industries due to technological advances in hardware that have enabled the creation of affordable, high-tech headsets and revolutionary projection solutions. The education, medicine, tourism, architecture, entertainment, and gaming industries are just a few examples of markets where virtual reality is increasingly being used. Users have the opportunity to experience virtual reality by active participation in the created photorealistic world in an increasingly direct way in real time. The virtual environment may have properties and options for operation that the reality itself has as well. It may also have additional or different properties that could not even exist in this form in the real world. Using advanced technologies, the creators of virtual spaces can create immersion, e.g., give a viewer the sense of being part of this artificial environment. Thus, virtual reality uses immersion to simulate interactive virtual environments or virtual worlds based on a model of real environments, in which users are subjectively involved and in which they feel physically present (Wohlgenannt et al., 2020).

New film technologies still raise more questions than solutions, as they clearly reshape the motion picture industry. This paper's aim is to focus on the film production phases from the perspective of workflow modeling. The selected aspects of traditional and XR film production are therefore explained to identify the priority determinants of both workflow organizations. The text is structured as follows: it starts with an introduction into the fundaments of computer-aided environments used in the film production. The research methodology is then outlined by the authors. An important part of the paper is the presentation of the production process shown on the basis of the workflow specifications. Next, case studies illustrating the features of cinematic VR, computer-generated VR and Virtual Production are investigated.

Discussed technologies affect didactic processes in higher educational institutions. In particular film schools, which have mastered the traditional production workflow of a feature or documentary film to perfection, it is needed to recognize the area of new XR technologies and decide whether to introduce it into the curriculum and how to implement it.

Methodological approach

The main aim of the text is to explore selected aspects of XR film production workflows for educational purposes and to identify the priority determinants of a traditional and XR film production workflows. The analysis is undertaken from the perspective of film school as HEI that tests ways of integrating XR technology into the

film production teaching programme. The following research approaches are used in the article:

1. Integrative literature review which looks at the relationship between XR environments.
2. Ethnographic field research which develops comparison criteria for workflow paths of XR film production to strengthen the quality of education in the field of filmmaking and film management while applying new technologies. The criteria are formulated and discussed following the phase-based progression of the film production, that is, development, preproduction, production and exposure. Then the features of cinematic VR production, computer-generated VR production and Virtual Production are analyzed and explained to ground the observations on the differences between traditional and XR workflows in film production.
3. Case study based on purposeful sampling which is widely used in qualitative research when analyzing information-rich cases (Patton, 2002). These cases are of central importance to the purpose of the research as they might facilitate students and teachers to understand XR film production workflows in the real life setting. The examined XR cases are an obvious choice for filmmakers and include:
   - "Sector" (2020, dir. Wojciech Olchowski in a co-production with the Visual Narrative Laboratory at the Film School in Łódź) – an immersive 360-degree video describing the workflow of a cinematic VR production;
   - "Nightsss" (2021, dir. Weronika Lewandowska and Sandra Frydrysiak) – a generative immersive experience showing the workflow of computer-generated VR production;
   - "Alejandro" (2022, dir. Mateusz Hernik) explaining Virtual Production workflow for a music video.

In this section, the starting point is the rationale behind the choice of a selected film production technology and also its potential of influencing the workflow of film production. The case study is among the most widely used qualitative methods in academia (Baskarada, 2014). Though it is subject to several limitations typical for qualitative studies, its application might see several advantages. The case study method helps to explore the ways film production workflows change depending on the technology used. It undertakes the analysis through a variety of lenses to reveal multiple facets of the phenomenon. What is more, it is explored within its natural context from the point of view of knowledge in making.

Computer-aided environments. Definition of terms

The terms discussed below refer to the subjects of virtuality, connecting the real world with virtual worlds and phenomena of experiencing virtuality. Virtual worlds cover "computer-assisted environments that attempt to recreate reality for the users using devices such as cameras, sensors, display, and projection devices" (Saxena, Verma, 2022, p. 3). The definition of virtuality can be considered here as any manifestation of simulation of the real or imaginary world, implemented either through computer-generated simulation or by creating conditions in which the experience simulates being in the real or imaginary world. **XR** (*extended reality*) combines a number of technologies related to the issues of creating and experiencing virtuality in the virtuality-reality continuum (Gownder et al., 2016; Milgram et al., 1994). As an umbrella term (Dwivedi et al., 2021), XR currently covers the following categories: **VR** (*virtual reality*) is an abbreviation for virtual reality – a computer-generated simulation of real world by means of physical, tactile, and visual dimensions (Rheingold, 1991; Greengard, 2019). Most often, VR tends to be connected with the use of VR goggles (*head mounted display* – HMD) such as the Oculus HMDs or the HTC Vive (Oriti et al., 2021), although CAVE (*Cave Automatic Virtual Environment* – room in which walls, floor and even ceiling are projection screens) projection solutions (Cruz-Neira et al., 1992) should also be included in VR. In the area of VR, two significant subcategories should be distinguished:

1. **Cinematic VR** represents the world around us using 360-degree cameras where a viewer develops a feeling of being there within the scenes and also chooses the viewing direction (Tong et al., 2021; Dooley, 2021).
2. **Computer-generated environment** – environments creating synthetic simulations of worlds using 3D computer design techniques (Kamińska et al., 2022).

Another category of XR is **AR** (*augmented reality*) – it is an abbreviation for augmented reality that combines digital content with the real world in which we live (Lemley, Volokh, 2018) to augment external reality. An example of AR is the image of the surrounding reality with computer-generated artifacts appearing in it. The last category is **MR** (*mixed reality*) – it is an abbreviation for mixed reality as a kind of augmented reality in which interactions between the virtual and real worlds are possible (Saxena, Verma, 2021). Due to the special ability of the above technologies to absorb the senses of the viewer or interactor, most of these technologies are generally referred to as immersive environments (Rubio-Tamayo et al., 2017).

In recent years, a special category of XR production has emerged on the film and television market – **Virtual Production**, which could be categorized as a MR, the mixed reality that combines and allows interactions between virtual and real worlds. However, as Deloitte analysts note, the definition of Virtual Production is not clear: "Every director and visual effects (VFX) professional will define virtual

production slightly differently, but at its core, virtual production is modern content creation" (Deloitte, 2020). Virtual Production could be potentially defined as a hypernym to cover all computer-aided production and visualization filmmaking methods combining VR and AR with computer graphic and game engine techniques (Li et al., 2022), however – in practice – it is related to a very specific and limited set of film and television techniques. In the film industry, Virtual Production refers to the technique of combining real and virtual worlds mostly in real time. The last criterion differentiates Virtual Production from traditional VFX where virtual (simulated) elements had already been widely used in postproduction (e.g. compositing). Real time seems thus to be the criterion used by the market to describe the new-coming technology – Virtual Production. The aforementioned virtual world is described as **Virtual Scenography** and it is implemented today using gaming engines like Unreal Engine or Unity. There are two subcategories for Virtual Production where different approaches to mixing the realities arise. In the first case the green screen technology is used – real objects are designed in front of green screen in a traditional way (Foster, 2014). The virtual background (3D world) is then composed in real time with real objects. Planned movements of the real camera must be tracked to adjust virtual (camera inside the 3D world) and real camera. Nowadays, this technique is very popular in the television industry where a virtual studio is fully designed in a 3D environment. This application of Virtual Production, however, does not require any particular use of tracking or 3D image quality – it is mostly static and simple scenography used. Another approach is to use the LED videowall (or rear projection as an alternative) on which an image from the 3D world is displayed and tracked with real camera movement. This technique is popular where cinematic quality, photorealism and complexity is required – in advertising or feature film.

We define traditional workflow as a progression in the production of a feature or documentary film that has been implemented and taught in Film Schools for decades: preproduction, production and postproduction.

XR studio workflow and comparison structure (criteria)

XR technologies, due to their nature, introduce a number of significant changes to the production flow. The nature of XR technologies could be very technology oriented (e.g. Virtual Production), computer science and programming based (e.g. Virtual Production, AR, any computer-generated environments) or experience conditions based (e.g. cinematic VR). Depending on the XR category several aspects have to be considered: equipment, sequence of the flow, staff, skills or exposure conditions. The XR workflow, defined as "a sequence of operations or activities performed by various entities or agents" (Vankipuram et al., 2011, p. 432) leading to the creation of an XR work, requires changes to modern production. The new

workflow for XR works will depend on the XR category as there are no two identical workflows (Arundale, Trieu, 2015). The first table presents comparison for selected categories: cinematic VR with HMD, real-time computer-generated VR with HMD and CAVE, Augmented Reality and Virtual Productions – both greenscreen and LED wall based. The table highlights XR specific and unique workflow work steps – it does not mention items which are not XR or non-XR technology specific like casting, budgeting or script development. First of all, there is no common workflow for all XR related productions. XR workflow will depend on the selected technique or XR category, however, all categories follow traditional phase based progression, that is: Development, Preproduction, Production and Exposure (the presentation phase). Highlighted blocks indicate the phases of the greatest effort required during the production process. For cinematic VR as well as computer-generated VR there are production and exposure phases. In cinematic VR the production phase requires significant effort including 360-degree camera shooting, lighting, spatial sound creation – these are new and challenging elements for the cinematic VR. Last, but not least, the exposure phase poses considerable challenges – safe and calm experience conditions, presentation technicians and assistants and HMD equipment (including battery charging). For computer-generated VR or Augmented Reality project situation it is quite similar. The main part of the process is the production itself, which consists of virtual scenography creation and programming in XR studio. These XR categories can actually be created in the computer studio itself. The exposure phase requires similar effort as before. An interesting change is introduced by Virtual Production. Here, a significant effort lies on the preproduction side. Before actual production in the virtual production studio, virtual scenography has to be designed, created and also programmed if needed. Apart from the technical challenges and complexity during production phase (LED wall calibration, camera tracking, etc.), this stage seems to be very similar to the traditional production.

Second table refers to staff and job positions considered in the XR workflow. Cinematic VR core competencies are related to 360° camera – this competence can be fulfilled by 360° camera technicians. An additional competence is related to the spatial sound. Sound technicians, designers, artists have to achieve spatial competencies in sound to support cinematic VR. For all computer-generated techniques like VR, AR and also Virtual Production there are some special competencies that can be divided into two categories. 3D artist is responsible for the 3D worlds creations including assets, textures, photogrammetry, lighting, visual effects, virtual camera, etc. 3D programmer on the other hand is responsible for interactions, user interface, optimization or equipment integration. In the production phase of Virtual Production, we may highlight two job positions. VP supervisor responsible for VP coordination process and VP technicians responsible for game engines (3D world projection, performance, etc.), tracking system, LED wall calibration, etc.

Any comparison of the production flows – whether with traditional workflow or with individual XR categories – can be made according to the following criteria:

- XR category to be compared
- Workflow phases
- The importance of the phase
- Work packages
- Staff
- Skills
- Education
- Equipment
- Costs
- Elements of creation

Table 1. Comparison of XR production workflows – work packages (selected)

Highlighted work steps	Development	Preproduction	Production	Postproduction	Exposure
Cinematic VR (HMD)	spatial design		360° camera, spatial sound	editing, post VFX, color grading, sound	HMD, gallery, WebXR
Real time computer-generated VR (HMD)	virtual scenography & spatial design	XR studio scouting	virtual scenography, programming, visual effects, spatial sound		HMD, gallery, WebXR
Real time computer-generated VR (CAVE)	virtual scenography & spatial design	XR studio scouting	virtual scenography, programming, visual effects, spatial sound		CAVE
Augmented Reality	application and virtual asset design	XR studio scouting	virtual assets, programming, visual effects, sound		glasses, gallery
Virtual Production (greenscreen)	virtual scenography design	virtual scenography, programming, VP studio scouting	virtual camera, movement tracking, light matching	editing, post VFX, color grading, sound	cinema, TV, streaming
Virtual Production (LED wall)	virtual scenography design	virtual scenography, programming, VP studio scouting	virtual camera, movement tracking, light matching	editing, post VFX, color grading, sound	cinema, TV, streaming

Source: own study.

Table 2. Comparison of XR production workflows – staff (selected)

Staff	Development	Preproduction	Production	Postproduction	Exposure
Cinematic VR (HMD)			360° camera technician, spatial sound designer		Presentation technician/ assistant
Real time computer-generated VR (HMD)			3D artist, 3D programmer, spatial sound designer		Presentation technician/ assistant
Real time computer-generated VR (CAVE)			3D artist, 3D programmer		Presentation technician/ assistant
Augmented Reality			3D artist, 3D programmer		Presentation technician/ assistant
Virtual Production (greenscreen)		3D artist, 3D programmer	VP Supervisor, VP Technician		
Virtual Production (LED wall)		3D artist, 3D programmer	VP Supervisor, VP Technician		

Source: own study.

Overview of workflows – is the virtual technology exciting and liberating for filmmakers?

The time of the pandemic showed that the construction of LED stages gave film artists the opportunity to create any film location without having to travel. Another value has emerged, based on real-time game engine technology and computer-generated VR. Filmmakers could observe and experience the vision they had just created. The director of the film and the cinematographer were given a tool to interact with their own world, which they could immediately observe, comment on, diversify, and above all, correct and tighten the shots or details that will be necessary during the postproduction period. Interestingly, unlike the traditional film production process, thanks to the virtual technology, they can immediately assemble worlds, regardless of whether they were created physically on a film set in a specific facility or in a virtual world. Virtual production uses various software packages that allow creators to combine both computer graphics and footage in real time. This advancement gives them the ability to create and render digital environments in

studios located anywhere in the world while cast members work on set. It is worth noting that this would not be possible due to a significant reduction in the time of filmmakers to rendering footage of several hours, days, and even weeks, which is influenced by the development of technology to build multicore and multithreaded processors. Due to this significant change, access to materials for image postproduction is basically instantaneous. Such activities are conducive to building a continuum by harmonizing the physical and virtual worlds, which seems to be an important value for filmmakers looking for ways to express their visions locked in their imagination, translated into film scripts.

It should be remembered that virtual reality techniques mean a set of various tools and programs that, depending on the needs of the film project, may include one type of visual effects or many different ones, e.g. animation of characters in real time, projection on an LED wall, development of CGI effects (*computer-generated imagery*) or creating a virtual photographic object. As a result, the adjustment of the composition and size of the film group will depend on the planned ventures related to the creation of virtual reality.

It is also worth noting that, apart from the selection of appropriate talents, the value of working in a virtual studio may be its unlimited access to the film equipment. Unlike traditional productions, if a specific film spotlight is not scheduled to be rented, it will not be available on the day of shooting. Therefore, the speed and possibilities related to the creation of the visual layer of the film increase. The change may also concern the plot of the film and, above all, the way of making difficult and complex scenes related to the implementation of pyrotechnic or stunt effects. In this case, the effects can be tested by the coordinators and the set manager in terms of safety and optimization of a particular way of implementing a given scene. By experimenting with virtual technologies, filmmakers can help and shorten the rehearsal and preparation period to a degree that significantly reduces acting and technical doubles in favour of storytelling.

Each film work is supposed to fulfil a function planned by its creator, but only the active reception of its recipients will decide about the meaning finally assigned to it. In the eyes of the creators, the film is created inside the imagination of the viewers and recipients. The interpretation is made by the recipients in the context of their own experiences, knowledge, current emotional state, etc., and thus does not entirely depend on the creator. In addition, it may be different for each recipient, so it will not always be in line with the intentions. The role of filmmakers is to fully understand the emotions and psychology of the characters they bring to life in their films. By controlling the design of the shot, they shape every visual element to create a strong emotional and psychological connection with the viewer. They try to determine what natural feelings and intuition are trying to tell them when they frame their films because they want to trigger, manipulate, and control the audience's emotions.

Cinematic VR production specifics

The production of film in cinematic VR (360-degree, 3D) requires specialized equipment and film services based on 360-degree 3D film cameras with an appropriate technical and software support such as editing station with an optimal processor, DIT station to review the materials, drones, camera dollying, etc.; also, specialization of work and new positions in the film crew. Moreover, specific professional terms such as "frame" are not commonly used in cinematic VR, rather filmmakers relate to the point of interest to attract viewers attention.

The organization of the shooting set requires the production department to turn off the so-called "dangerous zone", which is located about 2 meters from the cameras. For technical reasons, it is recommended not to place objects closer than 1.5 m from the camera, to determine where the comfortable 3D is located, and then it cannot be far away, which is most typical of seeing. If the distance is not respected, everything that will be in the scene in this zone will be blurred. So, all elements that could distort the shot should be removed. On the set of a traditional film, members of the film crew may stay on the set, following the directions and commands of the director and the set manager. The virtual production plan, which records the image of even several 360-degree cameras, changes the habits of the film team. This means that if an employee is needed and stays on the set many times, he has to put on a costume, impersonate a character, or blend in with the crowd or set design (Świerczyńska-Kaczor et. al., 2019).

By building the scene, unlike a traditional film, viewers can look at any place at any time. Therefore, if the director wants to draw attention to a detail prop or action that occurs in the upper left corner, it is best for a properly directed sound to direct the viewer to a place consistent with the script. It is then worth recording the sound after the shot, if the camera focusses on image quality instead of sound or takes care of a dedicated 360-degree sound recorder.

The process of image and sound postproduction takes much longer than in the case of the traditional one, due to the need to combine materials from several cameras into appropriate programs (Mistica VR, Insta Sticher). The content is merged, and then the angles are joined together (*stitching*). The horizon is repaired, and the angles are combined to make the image more consistent. Any objects that had to remain on the set, e.g. film and lighting equipment, are then removed by applying a reference background.

The dissemination of a Cinematic VR film can occur through galleries and rooms equipped with appropriate equipment (HMD). Without access to the right equipment, the screening of the film is possible in its "flat" versions, even as video published on streaming platform, when the viewer rotates the direction of viewing. In addition, you need to pay attention to motion sickness and take care of a bit more static shots.

Computer-generated VR specifics

Computer-generated VR movies provide viewers with maximum opportunities to create an illusory connection by being in the middle of action scenes and in a specific filming location. Here, virtual reality is a computer-generated effect of a three-dimensional spatial image or, more broadly, the environment, where you can see the interaction with the use of electronic equipment in a visible real way. Computergenerated virtual reality can be suggested to provide a more immersive visual experience than film playback, especially with the consideration that virtual reality artificially creates a sensory experience that can be sight, hearing, touch, smell, and taste. The filmmakers themselves were also expected to immerse themselves in the film's plot as never before. How then do these changes in the process affect the passive experience of the viewer watching in the cinema? Does the evoked potential of interactivity of a computer-generated VR film that transfers the view to the visual world of the film at a selected time open up new possibilities in the study and study of the material? Behaviour possibilities are also – looking from the perspective of the many different ways of telling stories – becoming close to the real world, immersions of everyday life, where the viewer is able to perform various activities, viewing elements, various props. These activities assist in the creation of artificial sensory pathways that, in their best technologically advanced form, are indistinguishable from the actual reality. The sense of presence in virtual reality results from the change in sensory perception, in which the immersive nature of HMD systems in the appearance of past experiences forces the brain to accept the virtual environment as occurring. The sense of presence is even stronger when one sees the possibility of using a natural method and making decisions regarding the conduct use. A take, e.g. 360-VR allows insight into the virtual environment, while computer-generated VR allows users to actively use the virtual environment with handheld controllers, thus the immersion factor (Bozgeyikli, Bozgeyikli, 2020).

Virtual production (virtual scenography) specifics

Virtual production, being inherently real-time technology, is technically complex and also relatively expensive. Entangled in modern technologies of creating and generating digital worlds, it requires unknown so far specialists equipped with appropriate skillset. This is particularly visible in the demanding film productions on LED walls. A shooting day on the LED wall is an important item in the production budget – savings associated with the use of the technology must offset these expenses. This is quite simple in the case of commercials or feature films – expensive locations and artefacts help reduce costs through virtualization. Staff education is in a completely different position. Virtual Production classes become unreachable

for film schools students. Occasional advanced workshops or rear projection seem to be the only options available for some educational institutions. Technical challenges related to virtual productions are: maintenance and setup of the wall (calibration, etc.), 3D preproduction including 3D design and programming and also camera tracking system. This last aspect of virtual production has been quite an intrusive and recurring problem throughout our classes. Also, some changes in the 3D project requested during the shooting may involve downtime that a traditional film crew is not used to. And this is where the new roles come in: virtual production technicians and supervisors.

Basically, compared to greenscreen, a virtual production on the LED wall is a significant simplification for cinematographers. The whole scenography (both physical and virtual) is visible therefore lighting design is much easier. Instead of unwanted green artefacts natural reflections of light appear. However, Directors of Photography and Virtual Production Supervisors must pay attention to image geometry (focal length for physical and virtual cameras), color temperature (3D world, projection, physical camera) and moiré effect when the LED wall is too close to the physical camera. Virtual production has also introduced a number of interesting opportunities and challenges for set designers. The main challenge is masking the border between the virtual and physical worlds as well as spatial thinking in both domains. We should not miss the fact that surroundings of the LED wall in general create a much more (compared to greenscreen) interesting and inspiring place for creators – mainly actors.

Case study: cinematic VR

Photo 1. VnLab Co-Production Documentary 360 Degree Film "Sector" (http://vnlab.filmschool.lodz.pl/category/pracownia-vr-ar/sektor/)

Source: Wojciech Olchowski, 2020

"Sector" (2020, dir. Wojciech Olchowski) is a festival-awarded, short creative documentary, shot in a form of an immersive 360-degree video. The film is a political protest performance, using butoh dance to express the controversial transformation of the landscape and biotope by human actions. The filming for "Sector" took place in September 2019 in a nature park on the narrowest part of the Vistula Spit, which was stripped of 10,000 trees in a few days. This place was intended for levelling and digging a canal, which would cause huge losses to the local nature and tourism. Immersive video is a type of video content that is designed to make viewers feel like they are inside the recorded space, environment or landscape. This is achieved by using an omnidirectional camera or a set of cameras to record a view in every direction at the same time. This filming style and technology allows the viewer to become more active by choosing their own point of view to experience a scene, providing a more personalized and realistic experience. The use of human actors integrated in the scene, taking the role of a narrator or used to motivate the user to look around, could provide an element of engagement and help the viewer to immerse in the story and environment. The concept of eco-performance, proposed by the Brazilian performing artist Maura Baiocchi, can be used to describe works that investigate the play of tensions between the body and the environment. Recording eco-performance in immersive video format is an interesting way to capture the interaction of a performer with the surrounding nature, because, especially with only one performer, most of the field of view is context of the presence of the human body. This makes the landscape or environment a partner of the performance, also because the viewer may choose to focus more attention on the image on the opposite side of the performer.

The project was developed as a co-production of a small independent team of authors with the Visual Narrative Laboratory (VnLab) at the Łódź Film School in Łódź. During series of group meetings in Łódź, various group of creators, producers, researchers and authors of selected by VnLab projects, supported each other, advised and shared the know-how in XR productions. Development stage was crucial, because it also included watching and discussing various XR experiences, which very much influenced the artistic and technological choices. The production was made by a very small team of two people on set, and two people in editing and composing music. Basic 360-degree cameras Go Pro Fusion were used. The medium of 360-degree film has certain limitations that make it necessary to limit the crew and lights on location. Because the cameras capture a view in every direction at the same time, it is difficult to hide lights and crew members, especially when shooting in open fields. The limited crew size also allows for a more agile and flexible production process. It allows for a more intimate and personal approach to storytelling, as the small team is able to adapt to the location and the story more easily. Furthermore, the use of basic 360-degree cameras also allows for a more cost-effective production process, as the cameras are relatively inexpensive, and the limited crew size reduces the overall cost of production. Additionally, as

the cameras are basic, the team can focus on the creative aspects of the production, rather than the technical aspects, and postproduction is possible on standard computers, as well as a more cost-effective production process in general.

Case study: computer-generated VR

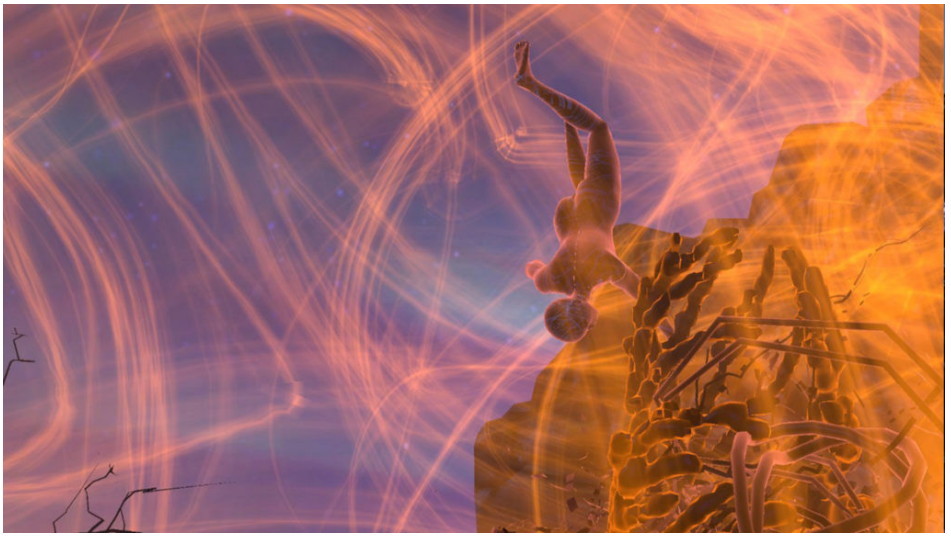

Photo 2. A frame from the "Nightsss" VR experience (official promo footage)

Source: Weronika Lewandowska and Sandra Frydrysiak, 2021

"Nightsss" (2021) is an artistic generative VR experience that was featured on various festivals, including Sundance New Frontiers. The film, directed by Weronika Lewandowska and Sandra Frydrysiak, is an immersive experience that combines elements of poetry, dance, and nature. The script is based on a spoken word poem of the same title written by Weronika Lewandowska, which uses sounds characteristic for the Polish language to create an onomatopoeic landscape that crosses language barriers. The film aims to evoke emotions through ASMR sound relations and rhythmic structures, as well as the choreography of the character the viewer will meet in the virtual world. "Nightsss" opens up the viewer for a sensual encounter with their own body, imagination and virtual space. The creators have used different qualities that can be applied to virtual space, such as generative forms with organic movement and organic forms exceeding the limits of predictable motoric, gravity and matter. The film combines sensual experiences with metaphor and language game to play with the perception of the viewer and create a synaesthetic environment. The relationship between the viewer, the poem, interactive sound space,

dynamically changing image, movement of the character and objects of the night creates a unique experience. "Nightsss" explores the possibilities of VR storytelling and dance in the context of the changing perception of technologically created spatial experiences and the development of the viewer's empathy in the embodied experience of virtual space.

Also this project was produced as part of, described above, VnLab projects' meetings at the Łódź Film School in Łódź. What's interesting about this production is that both authors/directors (Lewandowska and Frydrysiak) had no previous experience in generative media creations. They pitched the project based on a performed poem with elaborate descriptions of an imaginative visual level. Impressive and crucial for both artistic and technological decision-making by the supporting group, was Lewandowska's ability to already describe the desired body/sensual effects for the viewer ("immersant"). During the later stages of the work, the authors prepared a detailed script, based on a developed by VnLab leaders (Pola Borkiewicz and Jacek Nagłowski) "chart" with symbols of all planned action and immersants' reaction. The authors, later as directors, used this as a reference in the whole production process. In the early stages, authors considered many immersive media types, including 360-degree video, but finally they choose interactive, generative VR environment. The "Nightsss" was created as 6 degrees of freedom environment optimized for Oculus Rift S VR headset connected to PC computer. As an effect of one of the problems during production, there was a need to engage, on a limited budget, game developers whose work was essential for the actual realization. Project was made in Unity engine, and included gamedev professions: two people team for designing and creating 3D objects including motion capture and combining all elements into VR environment, and one interaction designer for Unity. The most important visual aspect of "Nightsss" is the choreography performed by Kaya Kołodziejczyk, and transcribed to 3D model of body in VR using Kinect. But this relatively simple to use technology was only useful for mapping (3D motion capture) of body movement/shape in one place. For recording movement in space of "stage" expertise of Wojciech Olchowski in 360-degree video was used, for preparing "movement template", as a couple of 360-degree recordings of choreography, for further developing movement in the VR space, by VR environment designers, based on watching by them 360-degree recordings in VR headsets. "Nightsss" is an ambitious project that explores the possibilities of combining different elements of generative media and virtual reality to create an immersive and unique experience for the viewer.

Case study: virtual scenography for a music video

Photo 3. A frame from the "Alejandro" music video

Source: Filip Gabriel Pudło, 2022

Here is the next example of the new workflow for a student's music video made in one of the classes at the Łódź Film School. "Alejandro" by Director of Photography – Mateusz Hernik – is a simple story of a young gangster which we watch to the protagonist's own rap rhythm. The video is a mix of standard and virtual productions – the virtual part presents the dark, but at the same time fascinating aspects of the hero's life. Two separate production styles have been used to split the gangster's life into two. The potential of the scenographic possibilities in the virtual domain was used to emphasize the separation from the everyday life of the protagonist and the fascination of gangster life. The most important possibility here is to create an unreal world – this can be achieved by building 3D environment with many possibilities of light (spot, ambient, color, etc.), construction (street elements, etc.), effects (like fog), embedded videos design. All this was made in a film hall without the need to search for physical locations. Moreover, the very technique of virtual scenography allowed for creative explorations that went beyond mere attempts to recreate reality – mostly in physical and virtual camera movement. The technology itself has revealed possibilities that have not been exploited in the film locations or studios so far – unusual movements (camera, scenography elements), scenography attributes control in real time, etc.

A significant difference in the production workflow was the need to prepare the 3D environment in advance. When the moodboard had been discussed and approved, the actual process of preparing the virtual scenography had begun. In this

particular production the Unity engine has been used. Assets acquired from Unity Asset Store were used to create 3D world – the dark city elements like buildings, streets, lighting, effects like fog as well as additional elements like billboards with videos prepared upfront. The 3D world design was based on ready-made templates that were adjusted according to the defined moodboard. The entire process took around two weeks. In the production phase the new technology introduced a number of possibilities for creating an image. In this case study the rear projection was used. First both virtual and physical cameras optics have been defined and adjusted. Then projection attributes like color and brightness. During typical process of physical lighting design the Director of Photography and the Virtual Scenography Designer could easily control the virtual 3D world – light intensity, light type (Spot, Area, etc.), items adding and removal, items position change, etc. While shooting, the raw image was visible in the preview all the time. During the filming the 3D world instance could be manipulated in real time, e.g. virtual camera movements or interaction with virtual elements (removal or adding). In this particular case study the preproduction as well as the production phases introduce significant change in the production workflow.

Conclusions

According to our study, it can be assumed that there is no single workflow for XR techniques. Each XR category follows a unique workflow that deviates to varying degrees from the standard workflow in traditional film production. In some techniques, the classical phases have become more or less significant – like preproduction phase in Virtual Production. On the other hand, other techniques had to significantly modify the traditional phases like production phase itself in cinematic VR and computer-generated VR. This knowledge and good practices should become part of the skillset and education of the future producers. The presented case studies clearly reveal challenges in terms of education, equipment, roles in the workflow. These new roles present challenges for institutions educating creators and producers interested in XR technologies. The equipment used in XR requires discussion of investment plans and a vision for making these technologies available to students. The case studies discussed above have revealed great opportunities for introducing new means of artistic expression. On the one hand, artists must properly select the technique for the artistic idea, on the other hand, each of these techniques provides new, unknown possibilities of shaping a moving image work. The authors of the article found that further scientific research is needed, and thus a more complete validation of the possibility of using the technologies described in the process of supporting film production. Particular in the context of the selection of specific techniques in terms of the director's intentions, taking into account that there is no single workflow, each time, this process should be composed for

the needs of the filmmaker in accordance with the principles of artistic creative diversity. The challenge is to preserve the work, especially when filmmakers use different techniques of artistic expression and technological solutions. Therefore, the question is how to configure the project development process (script, storyboard, and technical script), the shooting period (rehearsals with actors, minimum distance from the camera, and lighting), or postproduction (a part of the scene assembly technique) in creating XR content. Attention should be paid to uncertainty as to the direction of development of technological tools – technologies developed in R&D paths may turn out to be dead ends. They increase our knowledge, but have limited implementation possibilities. Here artistic research through artistic activities in the field of new technologies as a part of R&D and prototyping new experiences can bring value in new products and services. Uncertainty as well as the dynamics of change related to the development of XR technology should encourage educators to educate future-proof professionals – flexible and technology agnostic. The comparison of XR workflows clearly shows the need to build interdisciplinary teams. It is certainly a big educational challenge for film schools in particular and any HEI institution too.

The uncertainty on the one hand and high demand for XR technologies on the other suggest that educational institutions should not implement new programs too hasty or too slow. A critical and rational search for the golden mean is recommended here.

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