ISSN 2286-976X / Online: ISSN 2539-5513

RANGSIT JOURNAL OF SOCIAL SCIENCES AND HUMANITIES

Available online at https://rjsh.rsu.ac.th

The Research and Creation of Physical Art Object Through Virtual Reality

Gomesh Karnchanapayap

Faculty of Digital Art, Rangsit University, Pathum Thani, Thailand
Email: Gomesh.ka@rsu.ac.th

Received May 30, 2021 / Revised August 26, 2021/ Accepted September 22, 2021/ Publish Online September 23, 2021

Abstract

Art and technology have been evolving side by side. Humans invent technologies for their art-making quests, from various painting media to modern-day computer hardware and software. New technologies, such as digital painting and digital sculpture, provide artists convenience and flexibility to optimize their creative flow. The objectives of this research were 1) to study and explore Virtual Reality as a creative platform for creating new media artwork, 2) to create and output a new media artwork in a form of physical art through the use of additive manufacturing technology, and 3) to compare and analyze virtual art and its physical counterpart in a commercial art exhibition setting. An analysis of the audiences' survey data concerning the Virtual Reality art piece and physical artwork in art exhibition setting indicates that 1) Virtual Reality can be used to deliver a satisfying art-viewing experience and 2) most audiences would rather purchase physical art piece instead of Virtual Reality work because of product tangibility.

Keywords: *Virtual Reality, Art creation.*

1. Introduction

According to Oxford Learner's Dictionaries, the term "Virtual Reality" is defined as images created by a computer that appears to surround the person looking at them and seem almost real (Hornby, Turnbull, Deuter, & Bradbery, 2017). Although Virtual Reality has been around for many decades, the term "Virtual Reality" is often associated with the entertainment industry particularly computer gaming. Virtual Reality has a broad spectrum of applications including medical, military, architectural visualization, and even fine art. Since the dawn of Virtual Reality, forward-thinking artists have been trying to incorporate technology as an artistic medium. Since then, Virtual Reality artworks in the forms of installation art have begun to appear in galleries and exhibitions all around the world.

As artworks created using Virtual Reality technology require the audience to wear Head Mounted Displays to be transported to Virtual Reality art, one cannot easily purchase the artworks and take them home. Hence, for Virtual Reality artists, the most common revenue streams for this type of Virtual Reality art are either through exhibition tickets or project sponsorship. When the exhibition's over, these types of artworks leave no physical footprints behind as the artworks were created and displayed digitally during the exhibition as a visual experience through a physical head-mounted display powered by a computer. Oftentimes, one can only trace Virtual Reality arts in the form of documents may it be documentation videos or news.

1.1 Development of Virtual Reality artwork

Morton Heilig, an American cinematographer and inventor, is one of the scholars who is often credited as the pioneer of Virtual Reality. Heilig examined the relationship between film and viewer in 1955. This famous study revealed which of human's five senses is being used at any given point during the film viewing experience. According to the study, senses are being utilized in the following proportions: sight 70%, hearing 20%, smell 5%, touch 4%, and taste 1%. From this study, Helig began inventing and proposing a device for the cinema of the future (Payatagool, 2008). The Sensorama Machine was invented in 1957 and patented in 1962 (USC School of Cinematic Arts, online). Sensorama is a simulation device that incorporates visual, auditory, somatosensory, olfaction, and taste. The device claimed to stimulate the

users' senses; a screen for visual perception, audio speakers for auditory, vibrating fans for somatosensory, and a smell emitting device for olfaction (Poetker, 2019). While the device itself was very cutting edge and ahead of its time, this device never took off due to the high cost involved in the production of the contents and manufacturing of the device (Payatagool, 2008).

In 1961, Comeau and Bryan, two Philco Corporation engineers, developed the first Head Mounted Display with head tracking ability – the Headsight – by incorporating a video screen for each eye and a magnetic motion tracking system linked to a closed-circuit camera. The device application allows immersive remote viewing by the military. The device would detect the wearer's head movements which in turn instruct the movement of a remote camera, allowing the user to naturally albeit virtually look around through the camera lens (BCC Research Editorial, 2018). Approximately 8 years later in 1968, Ivan Sutherland utilized a computer instead of a camera to connect to a head-mounted display, which allows greater computing power to be displayed on the Head Mounted Display (Sutherland, 1968). An early application showed a 3D wire-frame virtual room that the user could explore by moving their head around. Since the Head Mounted Display is tethered with a large overhead weight support system hung from a ceiling, the machine came to be known as The Sword of Damocles.

Due to the past failures to launch, Virtual Reality was believed to be an unfeasible product for mass adoption (Scoble, & Israel, 2016). However, Oculus Rift, a successfully crowd-funded Head Mounted Display project had forever changed the landscape and perception of Virtual Reality technology. The Oculus Rift project was a brainchild of Palmer Luckey, who in 2011 was only 19 years old. He aspired to invent an affordable Virtual Reality headset for the indie gaming community. His prototype was highly praised by John Carmack, a living legend in the gaming industry responsible for multi-million-dollar games such as Doom and Quake. With this heavy momentum, he started a Kickstarter campaign offering game developers a chance to get Virtual Reality technology at a US$300-an affordable price point. The project took off and eventually surpassed $2 million in pledges from 9,522 backers (Kickstarter, 2018).

The consumer version of Oculus began shipping on March 28, 2016. The headset was well received by its patrons for its high quality of display and unprecedented affordability. In the wake of Oculus' success in penetrating the Virtual Reality market, many tech giants such as Sony, HTC, and Samsung began announcing their versions of Virtual Reality headsets. According to the study by Statistica research department, the Virtual Reality industry is growing at an accelerated pace, with the market size of consumer Virtual Reality hardware and software projected to increase from 6.2 billion U.S. dollars in 2019 to more than 16 billion U.S. dollars by 2022 (Gordon, 2020). Virtual Reality can truly now gain critical mass adoption for it to propel to the next level. At first, Virtual Reality attracts mainly game enthusiasts. However, the innovative technology also sparks more ideas and it did not take long for the world to begin imagining creative applications for Virtual Reality beyond gaming. In this study, the researcher would like to expand Virtual Reality usage as a creative tool for making physical art of black leopards.

The researcher was inspired by the tragic event regarding a rich poacher who invaded Thailand's protected forest and murdered the endangered creature. Although this horrendous act was national headline news, it soon fades. Thus, the researcher would like to use his artistic voice to make a statement about such crime. To gain a deeper understanding of the subject matter, the researcher went on and studied black leopards, their physical forms, activities, and ecology. Often black leopards are called black panthers. However, the term "Black Panther" is the melanistic color variant of any Panthera including the leopard (Panthera pardus) in Asia and Africa, and the jaguar (Panthera onca) in the Americas. According to the book "Comparative Genetics of Coat Color in Mammals," black leopards are most common in the dense tropical forests of south and southeast Asia. Their coloration enhances their ability to blend with the thick vegetation in the low light of the forests (Searle, 1968).

As illustrated by Eliot Goldfinger in the book, Animal Anatomy for Artists: The Elements of Form, you can see the proportion of leopards in comparison to other big felines (Goldfinger, 2004). Leopards are considered large felines; upon further investigation, you can see big cats may have different proportions. Baby leopards weigh only about half a kilogram and are about 13-18 centimeters long. The mother leopard has a gestation period of 93 to 100 days. Leopards, particularly in Asia, regularly give birth to just one cub (Animal Facts Encyclopedia, 2020). Male leopards are slightly larger than females. The average length and height of a full-grown male leopard are 183 and 66 centimeters while the average length

and height of a full-grown female leopard are 152 and 56 centimeters, whereas the males can weigh up to 54 kilograms while the female average is 40 kilograms. Leopards can live up to 23 years in captivity, however, their average lifespan in the wild is only around 12 years.

In this study, the researcher would like to explore the possibility of producing both Virtual Reality art and physical art as commercial art objects through the qualitative research process.

2. Objectives

1. To study and explore Virtual Reality as a creative platform for creating new media artwork
2. To create and output a new media artwork in a form of physical art through the use of additive manufacturing technology
3. To compare and analyze virtual art and its physical counterpart in a commercial art exhibition setting

3. Materials and Methods

3.1 Research Framework

The framework of this research is illustrated in Figure 1.

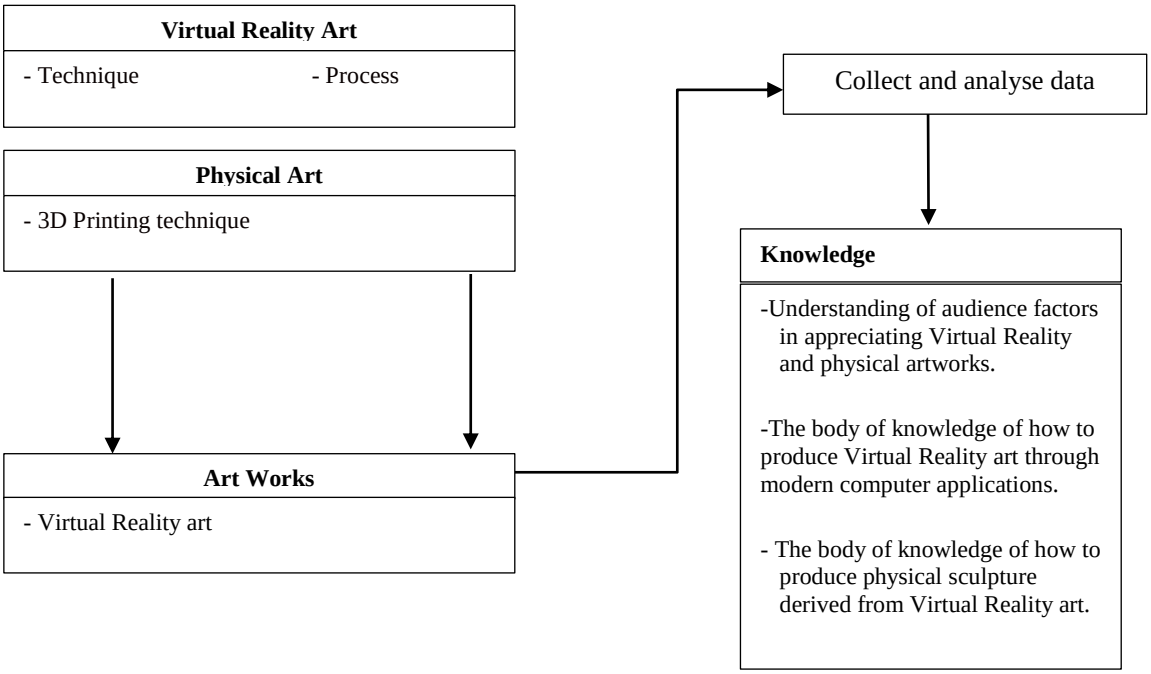

Figure 1 Research Framework

3.2 Methodology

3.2.1 Scope of research

The researcher studied the physiology of black leopards as the subject of artistic creation. The Virtual Reality artwork on the topic was developed using the software Google Tilt Brush. The physical artwork was refined from the exported Virtual Reality file using the software Pixologic ZBrush and 3D printed to produce a bronze sculpture through the wax casting method. Oculus Virtual Reality Head Mounted Display was utilized for viewing the Virtual Reality artwork while the physical artwork was displayed on an exhibition stand. This research collected field data from 115 samples of volunteers who have viewed and experienced both Virtual Reality and bronze artworks. The artworks were exhibited as part of the "Ror Sor 238: Zodiac Art" exhibition on October 25, 2019.

3.2.2 Research tools

The researcher used data collecting tools as follows: camera, interview questionnaire, electronic equipment such as telephone, computer, and devices to record pictures and data.

3.2.3 Data collection

Data were collected from the fieldwork which was conducted by observing the audience and asking survey questions. With this method of data collection, the researcher was able to acquire both qualitative and quantitative data necessary for this study. The research tools used are an interview questionnaire and a camera.

3.2.4 Physical output of Virtual Reality art

The idea of producing Virtual Reality art into a physical tangible sculpture is almost like the ability to conjure physical materials out of thin air, which could potentially be beneficial to many industries such as fine arts, toys, and other applications. 3D Printing is a technology that can transform a digital sculpture into a physical one through an additive manufacturing process (ISO, 2015).

There are many 3D Printing technologies invented described below.

Stereolithography (SLA)

This type of additive manufacturing technology began in the 1980s. In 1981, Hideo Kodama of Nagoya Municipal Industrial Research Institute invented an additive method for additive manufacturing (Hahn, 2018). Kodama created a product that used ultraviolet lights to harden polymers and create solid objects, which was a steppingstone of a widely adopted 3d Printing technology known as stereolithography (SLA). In stereolithography as invented by Charles Hull, the object is printed layer by layer, rinsed with a solvent, and hardened upon exposure to ultraviolet light (ISO, 2015).

Fused Deposition Modeling (FDM)

Fused Deposition Modeling is an additive manufacturing process developed by Scott Crump. It is the most common form of 3D printing today. To realize an object into a physical form, the printer heats a cable of thermoplastic into liquid form and extrudes it layer by layer (Mongeon, 2017). FDM works with a range of standard thermoplastics such as ABS, and PLA. According to a whitepaper published by FormLab, although the FDM technique is suitable for basic proof-of-concept models, FDM has the lowest resolution and accuracy when compared with SLA or SLS and is not the best option for printing complex designs (FormLab, 2020).

Selective Laser Sintering (SLS)

Selective Laser Sintering is another form of additive manufacturing. It uses a powder polymer to create objects by emitting a laser to fuse the powder, layer by layer, into solid shapes. Objects printed with SLS technology have a slightly rough surface finish, but almost no visible layer lines (ISO, 2015).

Based on the initial testing of the three different 3D printing technologies, the researcher selected SLA technology as the mean to output the Virtual Reality art in the physical form as this 3D printing technology provides high quality output and cost-effective.

The researcher investigated the following 3D Printing methods in order to decide the most suitable solution for this research.

3.2.5 Virtual Reality art and physical art Construction

The researcher studied the Google Tilt Brush application, which can be used to create Virtual Reality artwork. In this study, the researcher utilized Oculus Rift CV1 on the Oculus platform to create the artwork. The following are the creation steps.

Setting up the Oculus Rift Virtual Reality Head Mounted Display

The researcher ensured that the computer must be able to handle the high demand of performance the Virtual Reality headset is going to need. Oculus has released its recommendations of which graphics cards to use, the minimum requirement was NVIDIA GeForce GTX 970. Oculus installation program can

be downloaded from the website oculus.com/setup. The installation process took approximately 30 minutes requiring 1.22 GB of disk space. A Facebook account is required for using Oculus Virtual Reality headset as Oculus is a subsidiary company of Facebook. After attaching the Oculus Head Mounted Display and Oculus sensors to the PC, the installation software will go through the steps including inputting height and sensors' placements. The last step is to calibrate the Head Mounted Display by picking it up in all directions in front of the sensors until the software confirms correct detection.

Acquiring and using Google Tilt Brush software

As the researcher chose the Oculus platform for the study, Tilt Brush software can be purchased directly on the Oculus store at US$19.99. Since the artwork is created using Virtual Reality, it is imperative to learn how to use the input device. The Oculus Touch consists of a pair of handheld controllers, each comes with an analog stick, three buttons, and two triggers. Rings on the controller contain infrared Light Emitted Diodes (LEDs) that allow the controllers to be fully tracked in 3D space by the Oculus Rift system. With this, the movements and actions made by the controllers can be represented in the virtual environment.

Creating the Virtual Reality artwork

The researcher practiced Virtual Reality art creation by testing out paint stroke in Tilt Brush. There are 48 brushes in Tilt Brush populating across 4 brush pages. The Virtual Reality artwork in this research utilized Embers brush, Electricity brush, Streamers brush, and Disco brush. Figure 2 shows the brushes and their locations.

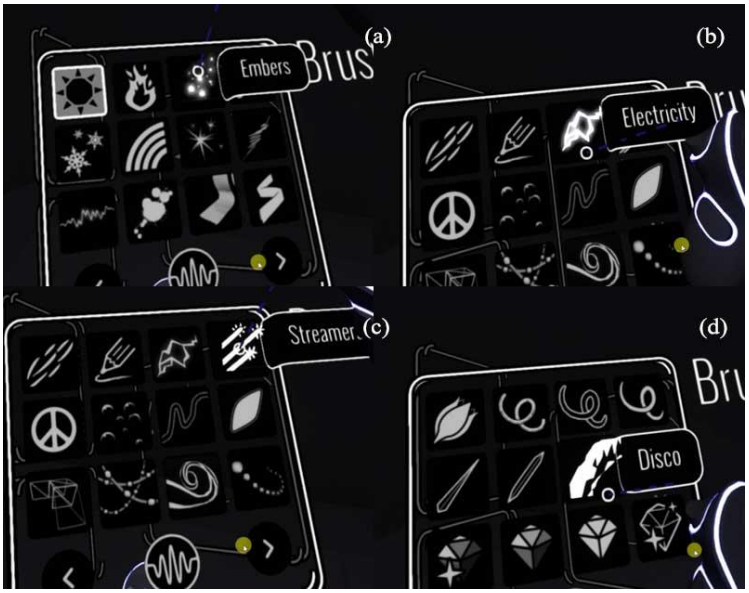

Figure 2 The artwork in this research was created using 4 brush types
(a) Embers brush on brush selection page 2
(b) Electricity brush on brush selection page 3
(c) Streamers brush on brush selection page 3
(d) Disco brush on brush selection page 4

By using Disco brush, the overall mass on the left side of leopards can be constructed as shown in Figure 3. Colors were used in this artwork to distinguish the gender of the creatures; dark blue representing male and pink representing female respectively.

The Electricity brush was then used to construct polygonal lines on the right side of leopards. Blue and pink colors were again used by the researcher to signify gender as shown in Figure 4.

In Figure 5, Streamers brush set to light green color was painted at the base of the artwork to create animated flowing streams. Embers brush was used to create animation of light flickering from the leopards.

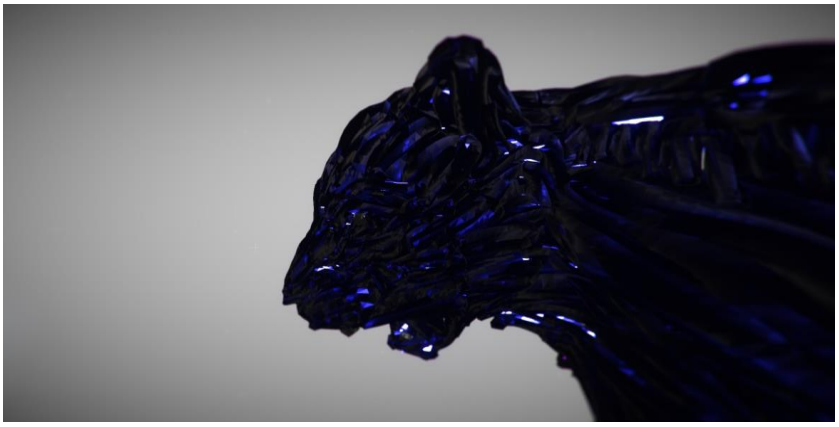

Figure 3 The form on the left side of constructed leopards using Disco brush strokes

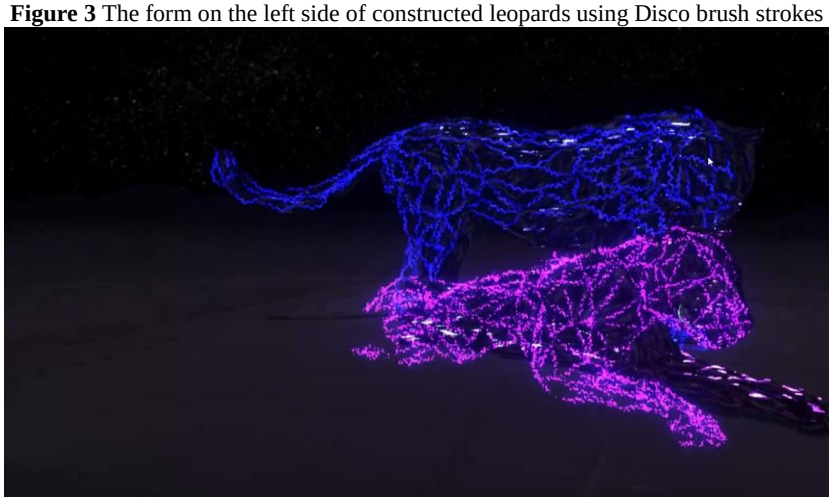

Figure 4 The polygional look on the right side of created leopards using Electricity brush strokes

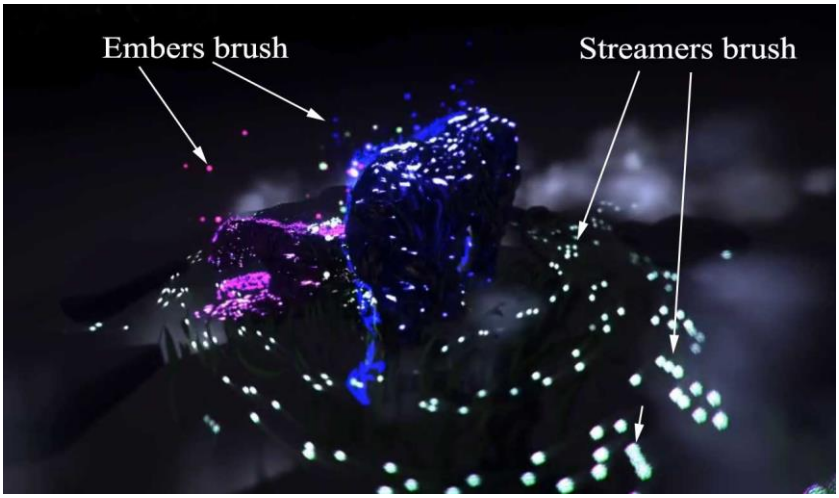

Figure 5 Streamers brush strokes create animated flow of streams on the floor while Embers brush strokes create flickering effect floating off the leopards

The researcher named the artwork “Silence Roar: The Last of Us ”. The title suggests a dim future of leopards. As the species continue being murdered by humans and no one can hear their cries for life, there might not be any leopards left in the forest except the ones in this Virtual Reality artwork. The design choice of this artwork reflects the message through the use of polygonal lines suggesting future leopards may exist only as 3D polygon models.

As shown in Figure 6, once the audience put on a Virtual Reality Head Mounted Display, the artwork can be experienced in full 360 degree. There are three family members of the leopard in the artwork; the standing father leopard on the left, the laying down mother leopard on the right, and the baby leopard in the middle of the scene. One side of each leopard’s drawn in a realistic style while the other side’s represented as connected polygonal lines.

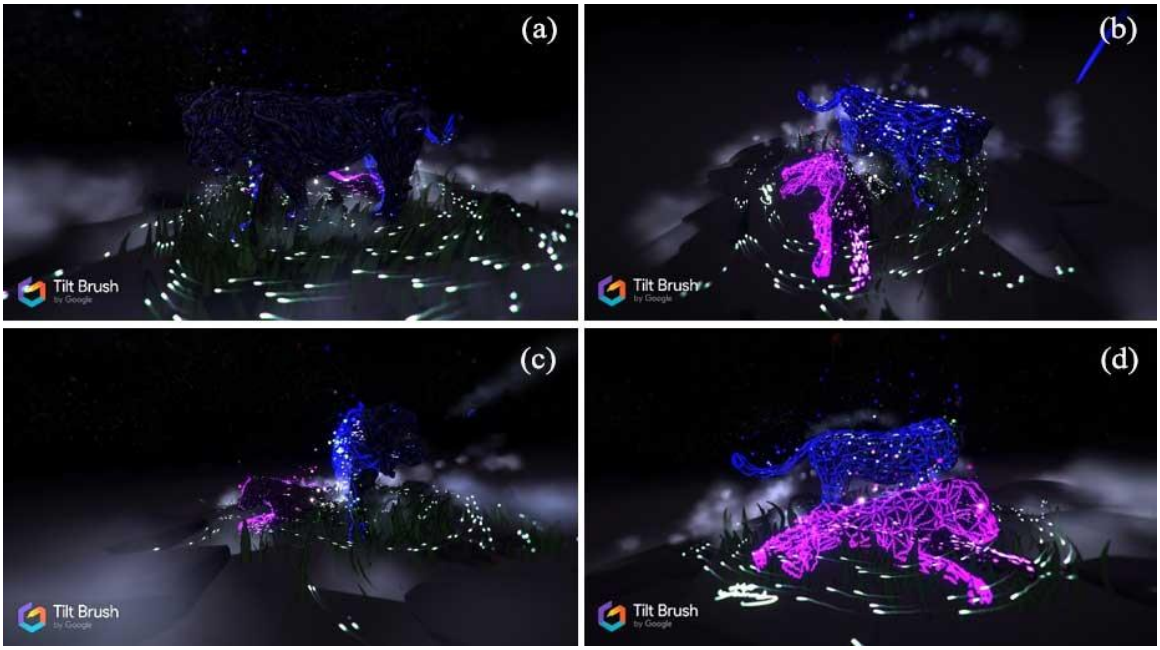

Figure 6 “Silence Roar: The Last of Us” as viewed through a Virtual Reality Head Mounted Display
(a) Left view of the artwork shows realistic style of leopards
(b), (c) The audience can move around within the artwork and the adjusted views accordingly
(d) Right view of the artwork shows leopards in polygonal style

3.2.6 Development of physical artwork

Digital sculpting

The artwork completed in the Google Tilt Brush was exported in Filmbox (FBX) file format. As this file format allows the artwork to be interchanged with other major applications, the researcher was able to import the file to Pixologic ZBrush for enhancing sculpt details. As shown below in Figure 7, the sculpture was refined in ZBrush portraying realistic style on the left side and polygonal style on the right side of the leopards.

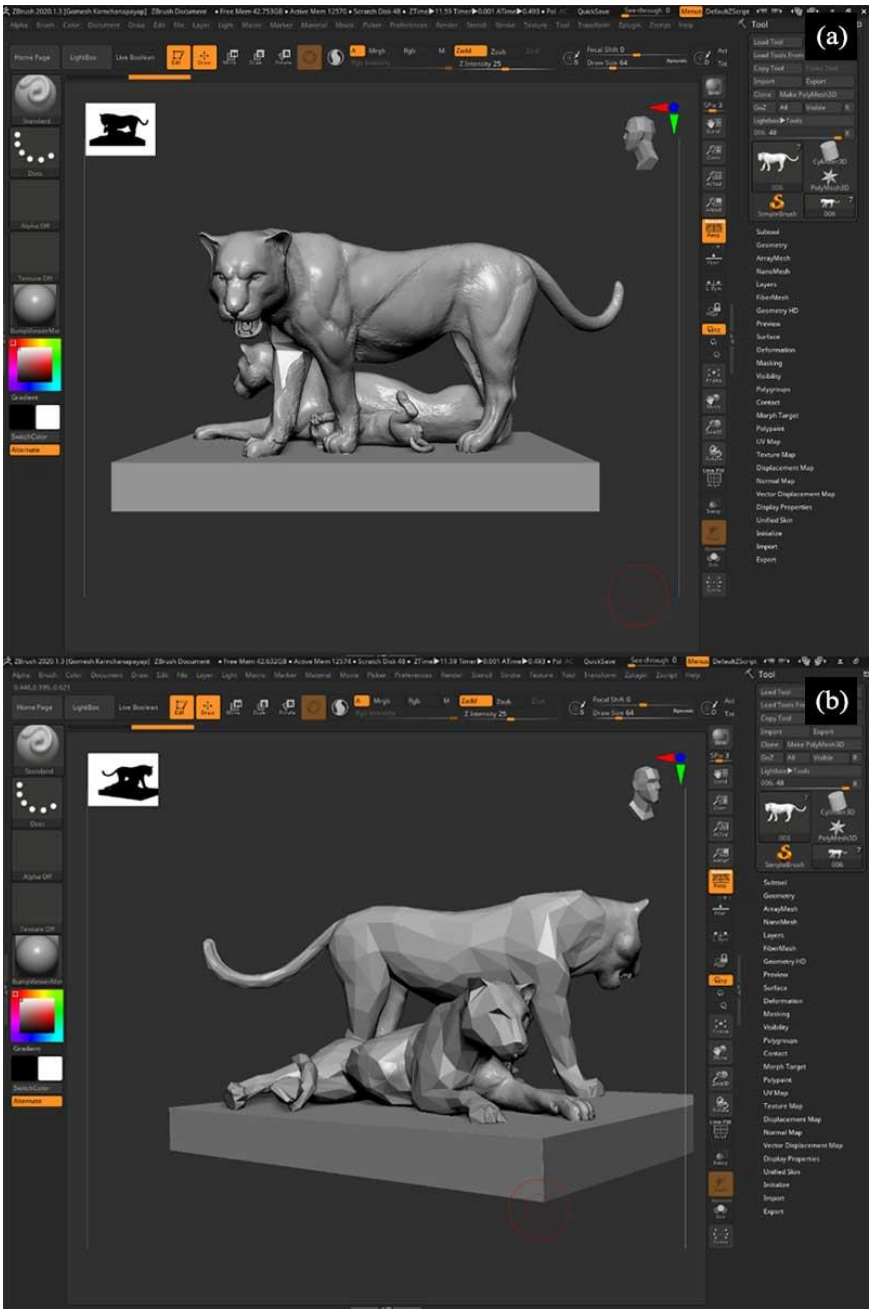

Figure 7 Digital sculpting of "Silence Roar: The Last of Us"
(a) Left view represents leopards in realistic style
(b) Right view represents leopards in polygonal style

3D Printing

The researcher exported the sculpt from ZBrush in the STL format, which allows the model to be physically printed with the additive manufacturing process. In this step, the researcher employed OctoPrint, a 3D printing service in Thailand. As shown in Figure 8, the researcher set physical dimension to the digital sculpture prior to printing out. The physical output dimensions were set to 23.2 cm (width) x 30.3 cm (length) x 13 cm (height).

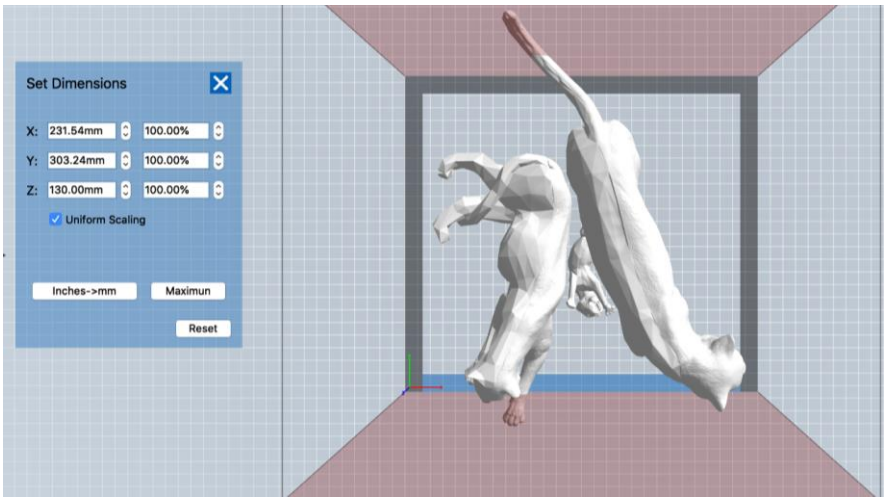

Figure 8 Top view showing physical dimensions setting of "Silence Roar: The Last of Us"

Bronze casting

3D printer used for outputting the physical sculpture was the Form 2 by Formlabs. The printed model was then molded and cast in bronze as a final physical product. Figure 9 shows the wax cast of the adult male leopard which was produced from casting a 3D print out.

Figure 9 Wax cast of "Silence Roar: The Last of Us" produced from 3D printing ready to be cast in bronze

The researcher tasked Thai Metal Crafters Bronze (TMC Bronze) foundry with the responsibility to cast and patina the sculpture. In Figure 10, the bronze sculpture was created through lost wax casting method.

Patina is a surface coloration generated by a chemical response on a metal surface. Patina may be a natural or man-made process since the process of placing patina on a sculpture of metal may add to the final appearance of a piece of art. In this study, jet black patina finish was achieved by applying hydrochloric acid atop the surface. The final look of the bronze sculpture with black patina's shown in Figure 11.

Figure 10 Bronze cast of "Silent Roar: The Last of Us"

Figure 11 The final look of the bronze sculpture with black patina
(a) Left side of the bronze sculpture shows realistic style
(b) Right side of the bronze sculpture shows polygonal style

4. Results

4.1 Virtual Reality and physical artworks exhibition

During the course of creating the artworks, the researcher was invited by an art curator, Mr. Yuttana Phongphasuk, to exhibit the artworks at "Ror Sor 238: Zodiac Art," which is a moving exhibition held on October 25, 2019 that takes the artworks to 4 art-centric locations; Fortune Town, Sathorn 11 Art Space, the Seven Art Gallery, and the Combine Café & Art Gallery. The event attracted many art lovers and enthusiasts. The researcher was able to show the artworks to 115 individuals. The poster of the exhibition's shown in Figure 12.

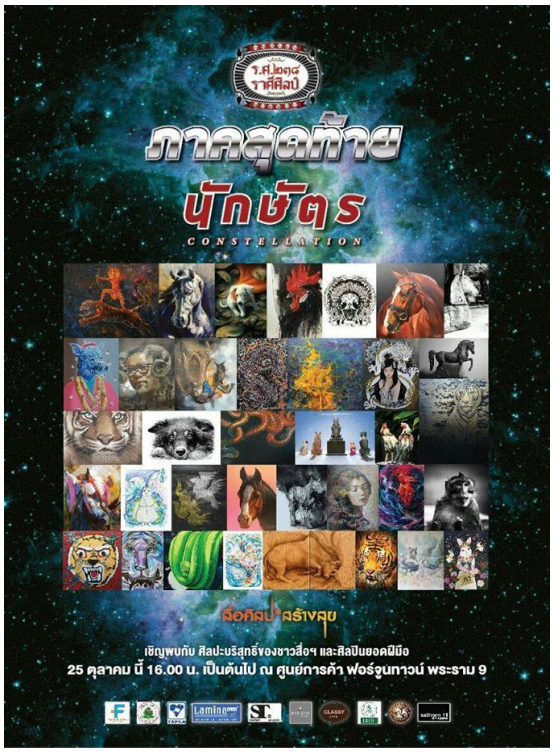

Figure 12 The "Roar Sor 238: Zodiac Art" exhibition held on October 25, 2019

Figure 13 shows how the researcher setup artworks for exhibition. The physical bronze sculpture was placed on a display stand along with the Virtual Reality Head Mounted Display.

Figure 13 The setup consists of a Head Mounted Display for viewing the Virtual Reality artwork and the physical bronze statue

With the play area of 3 x 3 meters, this spatial volume provides adequate space for audiences to view and interact with the Virtual Reality artwork. As the artwork can be appreciated from any angles and directions once wearing the Head Mounted Display. Within the Virtual Reality, the audience can experience the artwork virtually in full 3D. They can take their sight at any angle or even trying to touch the artwork as shown in Figure 14.

Figure 14 The stances of the audiences while viewing the Virtual Reality artwork
(a) Sitting down **(**Location: Combine Café & Art Gallery)
(b) Standing with hand movement for touching the Virtual Reality (Location: the Seven Art Gallery)
(c) Crouching (Location: Sathorn 11 Art Space)

4.2 Survey results

Due to the nature of the exhibition, the artworks were shown in 4 locations; Fortune Town, Sathorn 11 Art Space, the Seven Art Gallery, and the Combine Café & Art Gallery, which provided exposure of the artworks to a large amount of audience. Through volunteer sampling, the data were collected from 115 participating audiences.

Table 1 Virtual Reality experience of the audience

Experience in Virtual Reality	Count	Percentage
No experience prior to the exhibition	105	91.3 %
Have played Virtual Reality in the past	9	7.8 %
Utilize Virtual Reality for work	1	0.9 %
Total	115	100%

Table 1 depicts the Virtual Reality experience of the audiences. The majority of the audiences in this study had no experience prior to the exhibition. Only 7.8 percent of the samples had experienced Virtual Reality in the past, which indicates that the technology is rather novel to the audience especially in the area of Art.

Table 2 Satisfaction level of the samples viewing artworks in 2 mediums

Format	Very Satisfied	Satisfied	Fair	Dissatisfied	Very Dissatisfied
Physical artwork	17%	80%	3%	0%	0%
Virtual Reality artwork	45%	55 %	0%	0%	0%

Shown in Table 2, the study reveals that the audiences had a high level of satisfaction while viewing the Virtual Reality artwork. Comparing the two formats of the artwork, 45 percent of the audiences

rated very satisfied with the Virtual Reality while the rest 17 percent rated the same for the physical artwork.

Table 3 Pricing suitability level of the artworks

Format	Very Suitable	Suitable	Fair	Unsuitable	Very Unsuitable
Physical artwork	7.8%	75%	15%	2.2%	0%
Virtual Reality artwork	0%	4.3 %	22.7%	73%	0%

The listing prices for the artworks were determined by the cost of development and the materials of the artwork multiply by 3. The cost for producing the bronze was approximately 8,000 Baht and the Oculus head-mounted display price was around 12,000 Baht. Hence, the bronze statue was listed at 25,600 Baht and the Virtual Reality artwork was set at 36,000 Baht. Table 3 depicts audiences' views on the pricing suitability of both the Virtual Reality artwork and the physical bronze. While majority of the audiences was highly satisfied with viewing the Virtual Reality artwork, 73 percent rated the pricing is unsuitable. On a contrary, 75 percent of the audiences deemed the physical artwork pricing is suitable.

5. Discussion

Through an in-depth interview, the audiences informed that the Virtual Reality platform brings excitement and expands the horizon in the art-viewing experience. Not only can Virtual Reality technology be used as a new and emerging format for displaying artwork, but it can also transport the audience into the center of the artwork itself, providing an unprecedented level of audience immersion.

6. Conclusion

In "The Research and Creation of Physical Art Object Through Virtual Reality" the researcher focused on 1) studying and exploring Virtual Reality as a creative platform for art-making, 2) creating and outputting physical art through the use of Virtual Reality and rapid prototype technologies, and 3) comparing and analyzing Virtual Art and its physical counterpart in gallery display setting as sellable art pieces. Through this study, the researcher was able to create a process for producing artworks with the use of Virtual Reality. The process did not only allow the artists to create Virtual Reality artwork but, when combined with additive manufacturing techniques, could also export Virtual Reality arts into a physical one. The Virtual Reality arts, in cases around the world, are normally deployed as special exhibitions earning revenues through ticket sales. It means once the exhibition period's over, the Virtual Reality arts would also vanish along with the event. The physical realization process of the Virtual Reality artwork in this research allows the Virtual Reality derivatives to live on as physical artworks adding additional economic value to the artwork aside from ticket sales.

The majority of the audiences had a high level of satisfaction while viewing the Virtual Reality artwork. The technology brings a new sensation of viewing artwork by placing the audience at the center of the artwork itself. However, as sellable art objects, physical artworks are still more favorable among art collectors. Virtual Reality artworks require electronic devices to operate while physical artworks are exhibit-ready, which makes physical artworks more tangible and accessible in the eyes of art patrons.

The Virtual Reality arts may not be suitable as standalone purchasable artworks. Virtual Reality can, however, be used to complement physical artworks. While deploying alongside physical artworks, Virtual Reality can provide engaging activity during the exhibition that ultimately brings a memorable art-viewing experience.

7. Acknowledgements

The research of this article was supported by the Research Institute of Ransit University (69/2561). This paper and the research behind it would not have been possible without the support of my advisor, Professor Wattana Jutavipard. His enthusiasm, knowledge, and exacting attention to detail have been an inspiration and kept my work on track.

8. References

Animal Facts Encyclopedia. (2020) *Baby Leopard*. Retrieved from https://www.animalfactsencyclopedia.com/Baby-leopard.html

BCC Research Editorial. (2018). *The History and Evolution of Virtual Reality Technology*. Retrieved from http://blog.bccresearch.com/the-history-and-evolution-of-virtual-reality-technology

Formal. (2020). *3D Printing Technology Comparison: FDM vs. SLA vs. SLS*. Retrieved from https://formlabs.com/blog/fdm-vs-sla-vs-sls-how-to-choose-the-right-3d-printing-technology/

Goldfinger, E. (2004). *Animal anatomy for artists the elements of form*. Oxford, UK: Oxford University Press.

Gordon, K. (2020). *Statista Research Department. Virtual Reality (VR) - Statistics & Facts*. Retrieved from https://www.statista.com/topics/2532/virtual-reality-vr/

Hahn, B. (2018). *History of 3D Printing.* Retrieved from https://me3d.com.au/2018/history-of-3d-printing/

Hornby, A. S., Turnbull, J., Defter, M., & Bradbery, J. (2017). *Oxford advanced learners dictionary of current English*. Oxford, UK: Oxford university press.

ISO. (2015). *Additive manufacturing – General principles – Terminology*. Retrieved from http://www.iso.org.

Kickstarter. (2016). *A Brief History of Oculus, from Day Zero to Day One*. Retrieved from https://medium.com/kickstarter/a-brief-history-of-oculus-from-day-zero-to-day-one-8878aae002f8

Mongeon, B. (2017). *3D technology in fine art and craft: exploration of 3D printing, scanning, sculpting and milling*. London, UK: Routledge.

Payatagool, C. (2008). *Theory and Research in HCI: Morton Heilig, Pioneer in Virtual Reality Research*. Retrieved from http://www.telepresenceoptions.com/2008/09/theory_and_research_in_hci_mor/

Poetker, B. (2019). *The Very Real History of Virtual Reality (+A Look Ahead)*. Retrieved from https://learn.g2.com/history-of-virtual-reality

Scoble, R., & Israel, S. (2016). *The fourth transformation how augmented reality & artificial intelligence will change everything*. Florida, US: Patrick Brewster Press.

Searle, A. G. (1968). *Comparative Genetics of Coat Colour in Mammals*. London, UK: Logos Press.

Sutherland, I. E. (1968). A head-mounted three dimensional display. *Proceedings of the December 9-11, 1968, Fall Joint Computer Conference, Part I on – AFIPS '68 (Fall, Part I)* (pp. 757-764). https://doi.org/10.1145/1476589.1476686

USC School of Cinematic Arts. (online). *Inventor in The Field of Virtual Reality* (in Hugh M. Hefner Moving Image Archive). Retrieved from http://uschefnerarchive.com/morton-heilig-inventor-vr/