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The Creation of Bronze Sculpture Through the use of Virtual Reality Sculpting Technology

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ABSTRACT

Virtual reality, according to global megatrends, will change many aspects of human life. Virtual reality may improve sculpting over traditional methods. The study developed a virtual reality sculpture-making process. This research had three goals: (1) to examine Adobe Medium, the virtual reality sculpting software, and its tools; (2) to synthesize the process and critically practice it by sculpting 30 models; and (3) to use the process to create a bronze dragon sculpture. The study found that: (1) Adobe Medium is innovative virtual reality sculpting software that can be used to create complex sculptures; (2) many of the software's tools mimic real-world tools, so the virtual reality sculpting process is similar to actual sculpting; and (3) the researcher was able to create a complex bronze dragon statue with the process. The researcher believes that sculptors can use virtual tools with added benefits such as an immersive virtual sculpting experience unrestricted by gravity and the ability to gain vantage points while sculpting at any scale. Virtual reality sculpting allows the creation of complex physical forms. These insights are very valuable for sculptors who want to use modern technologies.

Keywords: Virtual reality sculpting; Practice based research; Bronze statue from virtual reality

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Introduction

Since the start of humanity, it has been understood that art and technology coexist and affect one another. With each technological advancement, the art-making process likewise evolves. The first known three-dimensional art form is the Löwenmensch figurine, which was discovered in 1939 in the German cave Hohlenstein-Stadel. The prehistoric sculpture was cut using a flint stone knife from mammoth tusk. Carbon dating has revealed the age of the sculpture to be 35,000 BC [1]. The majority of Egyptian sculptures from around 2500 B.C. were carved from limestone [2]. Early Greek sculptures closely resembled those of the Egyptians in that they were carved from stone and later took on a more realistic appearance by incorporating marble [3]. In the past, mankind relied on carving solid materials such as ivory or stone to create sculptures. Clay was a significant contributor to the development of sculpture because it was flexible and allowed the artist to alter the form by adding and deleting easily. The reddish-brown Terracotta was the origin of the artistic sculpting medium [4]. Numerous clay varieties and modifications were created to meet the needs of sculptors. Before the introduction of ZBrush, a digital sculpting software, in 1999, clay was the standard material for sculpture. The software was awarded the 1999 Innovation Award by Computer Graphics World [5]. Digital sculpting employs software that enables the manipulation of digital objects as if they were made of clay. This digital clay technique enables sculptors to modify two-dimensional shapes projected on a monitor using a pen tablet. Medium, a digital sculpting application compatible with virtual reality headsets, was released in 2016 [6]. The software enables sculptors to immerse themselves in a virtual environment by wearing a head-mounted display and manipulating objects directly using controls. Can virtual reality give sculpture with more benefits? To demonstrate the effectiveness of virtual reality sculpting, the researcher poses as a practice-based research topic the process of creating sculptures using virtual reality.

Research Objectives

1. Examine Medium, the virtual reality sculpting software and its tools.
2. Synthesize a virtual reality sculpting process and critically practice by sculpting 30 models with the process.
3. Create a bronze dragon sculpture using the virtual reality sculpting technique.

Research Framework

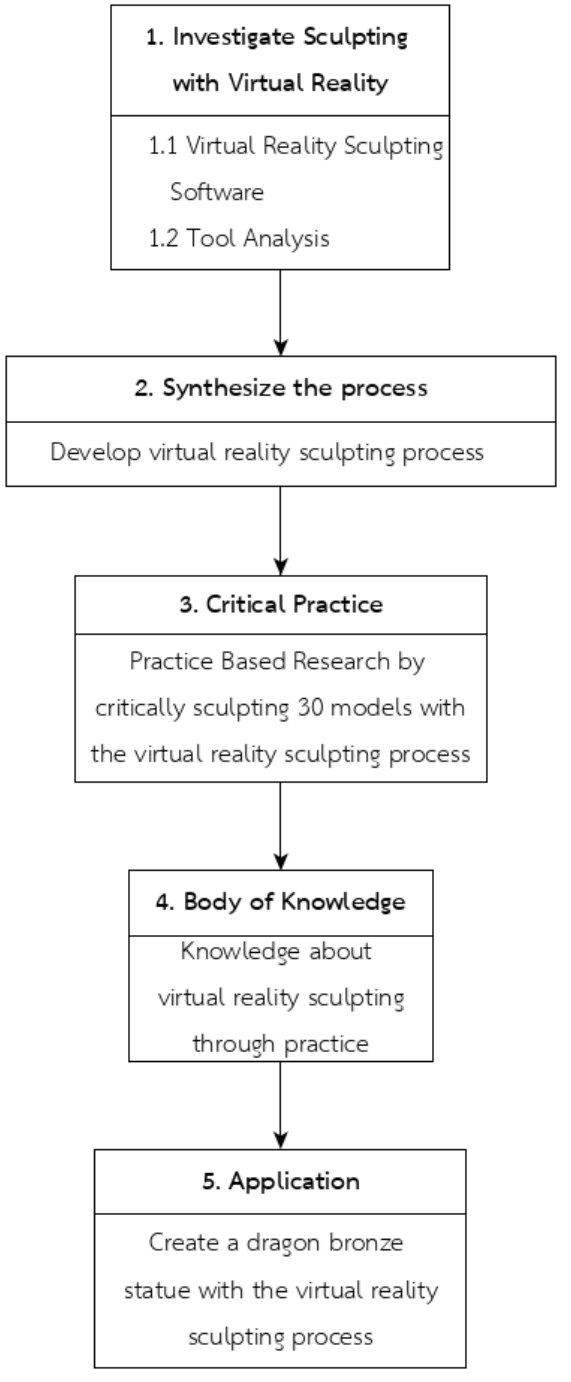

Figure 1 The framework of the study

Research Methodology

1. Investigate Sculpting with Virtual Reality Technology

1.1 The Virtual Rality Sculpting Software

The researcher began by investigating the available virtual reality sculpting software. In 2023, there were five popular programs for creating virtual reality models: Gravity Sketch, Google Blocks, SculptrVR, Arkio, and Adobe Medium. GravitySketch is a piece of software that employs NURBS surface modeling and polygon modeling. Google Blocks is software for constructing low-polygon models. SculptrVR resembles a child's sandbox and enables users to sculpt. Arkio is a modeling application designed to produce architectural objects. Medium by Adobe is a sculpting application. [7] Two programs, SculptrVR, and Adobe's Medium, are suitable for studying virtual reality sculpture, according to an initial assessment. SculptrVR has only a few hundred users, according to its official Facebook page (https://www.facebook.com/sculptrvr), whereas Adobe Medium has over 5,000 members (https://www.facebook.com/groups/mediumbyadobe). Therefore, the researcher selected Medium by Adobe as the study exploration software.

1.2 Tool Analysis

The virtual reality sculpting application was installed on the Predator Helios 500, a VR-capable laptop equipped with an Intel Core i7-8750H 2.2GHz processor, an NVIDIA GeForce GTX 1070 (8GB GDDR5) graphics card, and 64 GB of RAM. During the investigation, an Oculus Rift S virtual reality headset with a single fast-switch LCD 2560x1440 panel operating at 80 Hz was utilized [8]. Examining what each tool does and what it can be used for, a thorough analysis of each tool was conducted.

2. Synthesizing the Process

By understanding what each tool does, the process of virtual reality sculpting can be formulated. The synthesized process is shown in the "Research Results."

3. Critical Practice

Based on the process synthezised, the researcher practiced the formulated process by sculpting models. The researcher selected the ogre head as the subject for this exercise because the physiological characteristics of ogres with horns and fangs would be challenging to sculpt and could be used to test the limitations of the virtual reality sculpting tool. The decision to sculpt 30 models across a span of 30 days is because the researcher would like to keep a manageable timeframe for this step while allowing the improvement of virtual reality sculpting skill.

4. Body of Knowledge

Through practice-based approach, the researcher gained insight on how to suitably utilize certain brushes to ontain specific effects.

5. Knowledge Application

In the end, the researcher put his knowledge to use by creating a more complicated model, which was a bronze sculpture of a dragon. The research results present the full procedure, beginning with sculpting in virtual reality, exporting the file for 3D printing, and casting the printed model in bronze.

Research Results

1. Investigating Oculus Medium as the Virtual Reality Sculpting Solution and Analysis of the Virtual Reality Sculpting Tools

Oculus Medium is a software for digital sculpting that is compatible with virtual reality head-mounted displays and offers six degrees of movement control. The software is accessible exclusively through the Oculus Rift platform and was released on December 5, 2016. On December 9, 2019, Adobe acquired Oculus Medium and renamed the product "Medium by Adobe" [9]. The software needs the user to interact with the two controllers using both hands. The default non-dominant controller is the left controller. The right controller is the tool controller for a specific tool operation.

Detailing the virtual reality sculpting program indicates that each tool is best suited for a specific sculpting activity. The clay brush imitates the process of adding and removing clay from a sculpture. The default clay shape is a sphere, which can be altered to a cube or capsule. The application allows the user to apply clay with a single or continuous stroke. When configured to remove clay, this instrument imitate carving. The expanded brush adds outward volume to the area being treated. The researcher was unable to identify a comparable operation in the actual world. In physical sculpture, the artist must still add clay to the surface in order to get the desired volume. The move brush is one of the most potent brushes, allowing the user to shape the sculpture swiftly and simply. The brush mimics the process of kneading and shaping clay into the desired shape. The flatten brush enables the user to flatten a surface in a manner comparable to pressing a firm, flat object onto clay, leaving behind a smooth surface. The swirl brush gives the applied area a twist. A clay layer can be sliced and separated by the trimmed brush. This gadget resembles a wire clay cutter with two handles. Similar to the actual world, the sliced pieces will be separated from the original. Similar to what heat does to plasticine clay by melting or softening the substance, the smooth brush helps to smooth the surface.

Table 1 Comparative analysis of VR and Real-World tools required for sculpting operations

Operation	Real-World Sculpting Tool	Virtual Reality Sculpting Tool
Add clay	Clay material	Clay brush / Inflate brush
Create rough form	Knead and form by hands	Move brush
Flatten surface	Apply flat rigid surface on the sculpture	Flatten brush
Curl form	Bend the form	Swirl brush
Separate parts	Cut with double handle wire clay cutter	Cut brush
Smooth surface	Apply heat to the sculpture surface (Plasticine)	Smooth brush

As shown in Table 1, Adobe Medium's core philosophy seems to be to create an immersive sculpting environment with tools that imitate real-world processes.

2. Synthesizing the Virtual Reality Sculpting process

By donning the Oculus Rift-S Head-Mounted-Display, the user is transported into the Adobe Medium software's virtual environment. Within the construct, the user is presented with a blank infinite working area with a single empty sculpting layer set at a low resolution (Figure 2.). While Medium attempts to simulate real-world sculpting, there are a few controls to learn in order to navigate the environment. To zoom in, press and hold both grip buttons and pull the controllers apart to enlarge the scene's elements. To zoom out, press and hold both grip buttons, then pull the controllers closer together to shrink the scene's elements. In addition, Medium may be utilized in symmetry mode, meaning the sculptor only needs to work on one side of the artwork and the modifications will automatically be reflected on the other side.

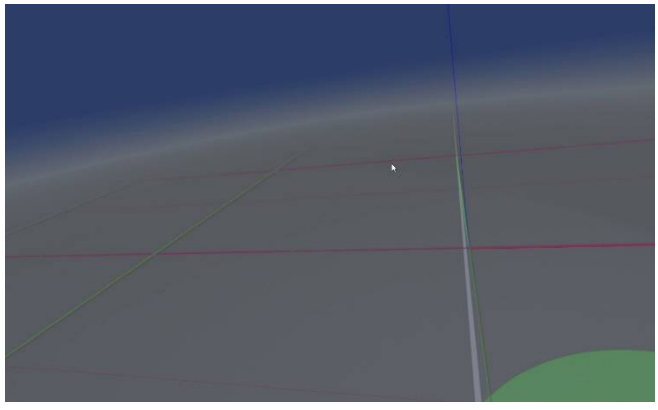

Figure 2 The default scene of Adobe Medium contains an infinite space with an empty sculpting layer

The resolution of the sculpting layer represents the malleability of the digital clay substance. There are only eight tools accessible via the analog button on the non-dominant controller. When pressed, the tool menu will appear as shown in Figure 3.

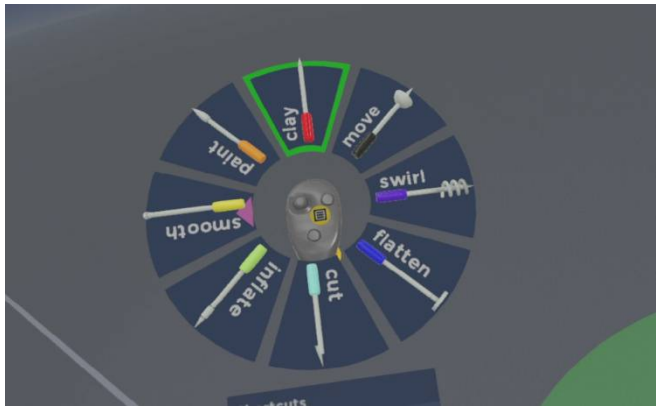

Figure 3 Tool selection menu can be accessed by pressing the analog button on the non-dominant controller

The user can select a certain brush by hovering the right controller above the menu and clicking with the right index finger. After selecting a brush, the user can simply position his right hand in the designated area and press the index finger to begin creating. The medium's objects are of real-world proportions, allowing you to shape your work as if it were physically existing before your eyes. Figure 4 shows how the researcher commanding

the virtual reality sculpting software with both hands. Once the researcher had a clear understanding of how to modify shapes using the virtual reality sculpting software, he was able to analyze and synthesize the virtual reality sculpting process.

Figure 4 The researcher while sculpting in virtual reality

While sculpting steps may vary from model to model, the Figure 5 below illustrates the technique and tool usage considerations.

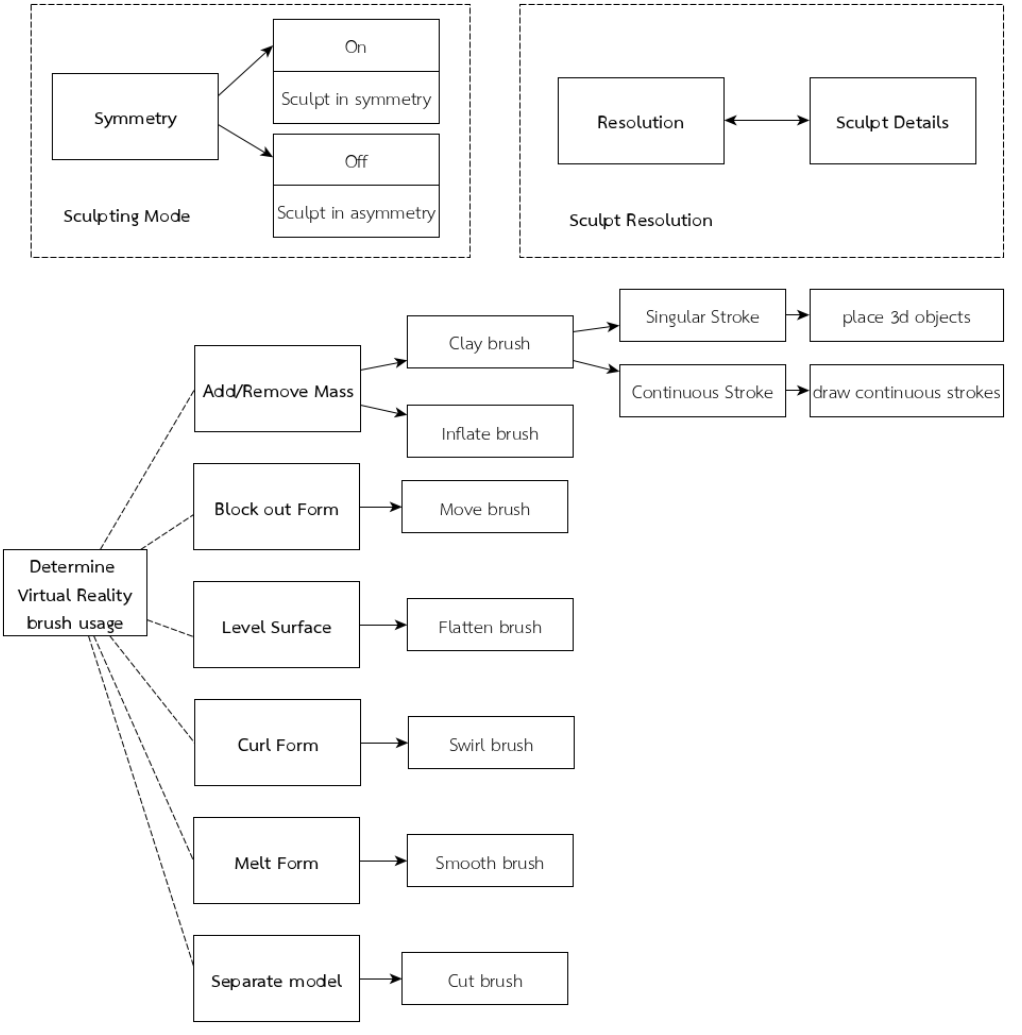

Figure 5 The process for considering virtual reality sculpting tools

The researcher defines the process of considering virtual sculpting tools as follow:

1) Symmetry sculpting mode. This is highly suggestible should one wishes to create a symmetrical model. Otherwise, this can be omitted.

2) Clay brush when set to singular stroke mode can be used to place a single instant of a primitive such as sphere, cube, or cylinder. When set to continuous stroke, continuing forms such as hair strands can be created.

3) Inflate brush can be used to increase volume on certain parts of the surface.

4) Move brush is suitable for forming the overall shape.

5) Flatten brush to level the surface.

6) Swirl brush to curl parts of the sculpture.

7) Smooth brush can be used to melt or blend surface.

8) Cut brush can be used to separate sculpture to different parts.

9) Increase the sculpture resolution allows more details to be sculpted.

3. Critical Practice

The next stage of research is to find a good subject for critically practicing the virtual reality sculpting process. According to the Merriam-Webster dictionary [10], ogres are grotesque beings with horns and teeth, which makes them an ideal subject for testing various sculpting brushes. The researcher created thirty ogre head sculptures using the virtual reality sculpting process. Through artistic practice, the researcher obtained a comprehensive understanding of how to make digital sculptures using this technology. Figure 6 demonstrates the use of brushes on a sculpted ogre head.

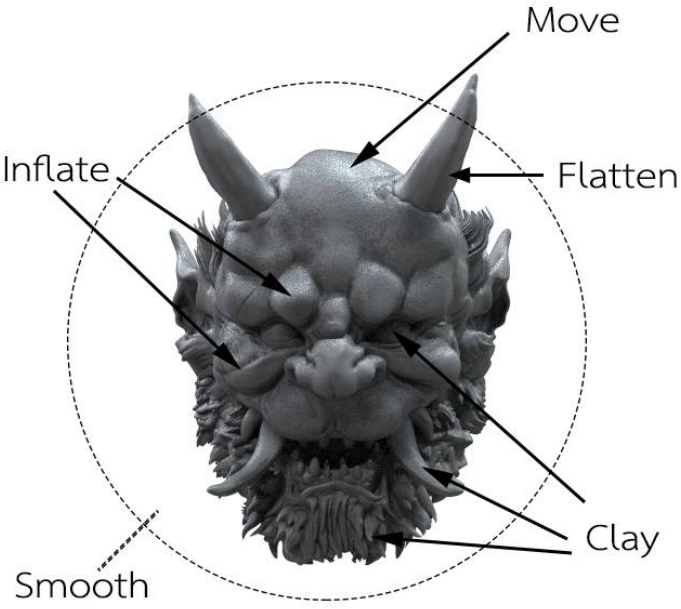

Figure 6 Brush usages on the ogre head sculpt

After thirty ogre heads were sculpted using virtual reality sculpting process (Figure 7), the researcher found the procedure to be highly productive. The researcher limited the time given to sculpting each head to 30 minutes to determine how much could be accomplished in that time frame.

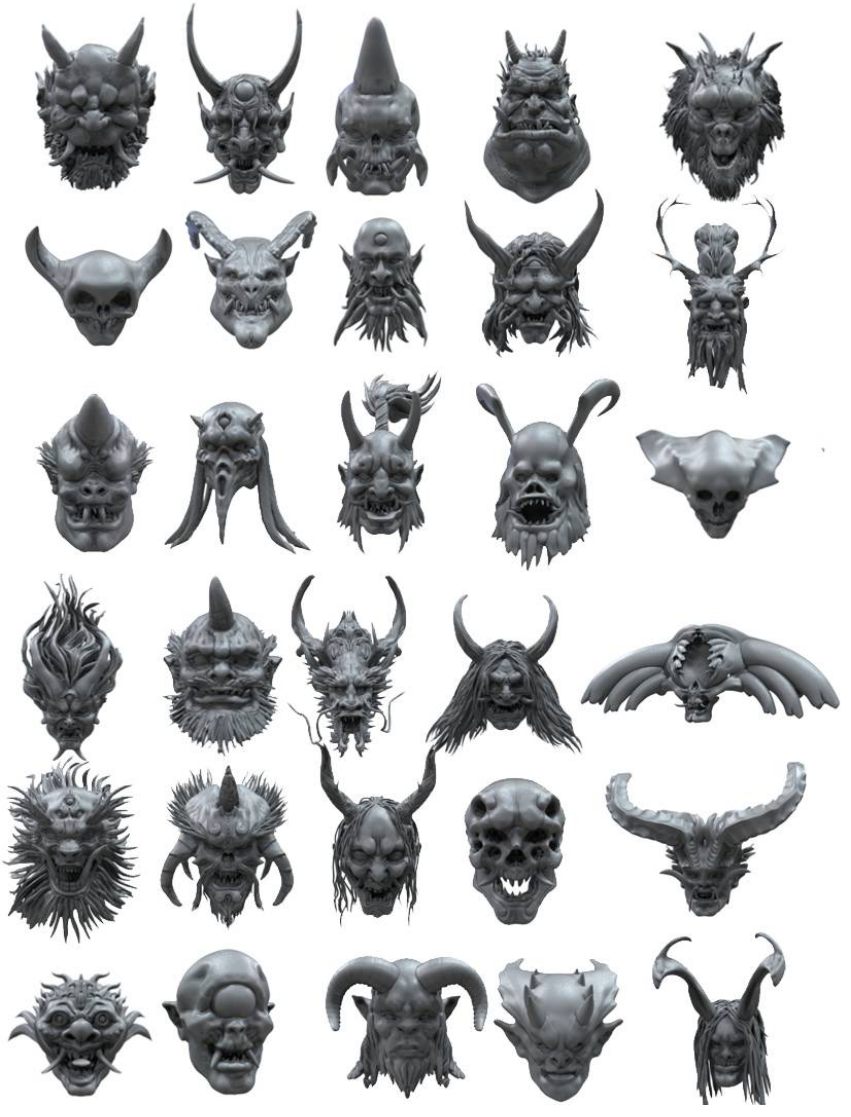

Figure 7 The virtual reality sculptures from the practice-based research

4. Virtual Reality Sculpting Knowledge

The researcher learned via critical practice that the virtual reality sculpting process is extremely comparable to physical sculpting. As in actual sculpture, it is better to begin with a loose form. To accomplish this with the Medium virtual reality sculpting tool, place a digital clay mass with the Clay brush set to a single stroke and begin digitally kneading the figure with the move brush. The smooth brush can be used to refine the surface's texture. Utilize the inflate brush to add or subtract volume from particular locations. With

the clay brush, eyeballs, horns, teeth, and hair can be added. Apply the flatten brush to portions of the surface, such as the side of the horns, in order to flatten them. After the primary form has been constructed, the model's resolution should be increased. The increase in resolution enables the sculptor to add more details to the digital model, analogous to adding details to solidified clay. Continue refining the sculpture and increasing its resolution as necessary to attain the desired aesthetic. With the virtual reality sculpting technique, intricate forms, such as interweaving forms, that are difficult to sculpt in the actual world may be created with a few simple strokes.

Sculpting in virtual reality places the sculptor in a specialized virtual environment. Consequently, the subject appears virtually in front of the sculptor, providing a vantage position. In virtual reality, in contrast to sculpting on a display, where the sculptor must use a mouse or pen tablet to rotate the subject's view, the sculptor can simply turn his/her head to observe the subject. With this benefit, the sculptor can naturally go forward, backward, laterally, and vertically, as well as up and down. This can be used in sculpture to produce intricate shapes or forms. Sculpting in virtual reality also eliminates issues regarding gravitational force and the artwork's weight. The sculptor can raise and scale the subject to the desired size without physical limits.

5. Knowledge Application: A Dragon Bronze Statue using Virtual Reality

The researcher learned via critical practice that the virtual reality sculpting process is extremely comparable to physical sculpting. As in actual sculpture, it is better to begin with a loose form. To accomplish this with the Medium virtual reality sculpting tool, place a digital clay mass with the Clay brush set

5.1 The Design of the Dragon

On the design of the dragon, the researcher collaborated with Mr. Somsak Mahamongkol, a renowned Thai artist. The initial pencil drawing on paper depicted a single perspective. The design of the dragon is a more complex one compared to the ogre heads, with intricate details and challenging forms. For the purpose of this research, the artist permitted the researcher to convert the two-dimensional sketch into a three-dimensional form directly in the virtual reality sculpting software.

Figure 8 The initial sketch of the dragon by Somsak Mahamongkol

5.2 The Virtual Reality Sculpting Process of the Dragon

With the artistic license given by the original artist, the researcher then sculpted the initial form using the virtual reality sculpting process achieved in the preceding step. The researcher decided to change the position to a coiling one because the final sculpture must be able to hold its own weight (Figure 9).

Figure 9 The initial form of the dragon in virtual reality

The researcher was able to effectively adjust the pose and evaluate the structure using the virtual reality sculpting technique. By using the clay brush, the body of the dragon, the tentacles, and the frills can be created in an instant. The inflate brush was used constantly to precisely add primary forms. The smooth brush was used on a regular basis to control the surface. The researcher then created a still image of the sculpture in Luxion Keyshot for visual inspection. The outcome is illustrated in Figure 10.

Figure 10 A still render of the dragon model in its initial stage

By making the model's resolution higher and using the inflate brush, more details were added to the sculpture. Using a clay brush, the scales of the dragon were added one by one. The entire procedure closely resembles sculpting in real life. Once the details were added, the model was ready to be exported. The result of this stage is shown in Figure 11.

Figure 11 A still render of the dragon model ready to export

5.3 Preparing the Model for 3D Printing

The model was exported from Adobe Medium in OBJ format, which is compatible with ZBrush, the industry-standard digital sculpting software for preparing 3D print outs (Figure 12).

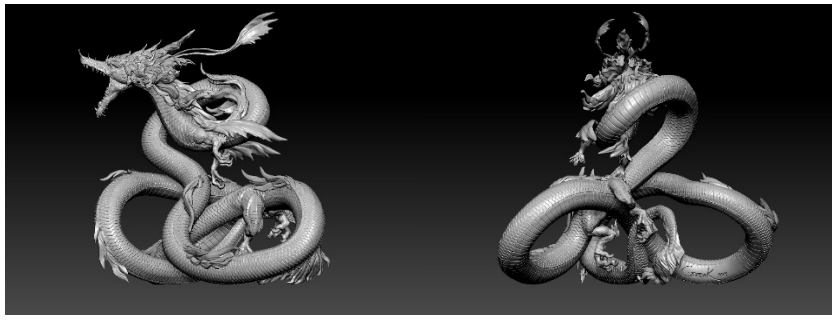

Figure 12 The dragon model in ZBrush

The model was exported from Adobe Medium in OBJ format, which is compatible with ZBrush, the industry-standard digital sculpting software for preparing 3D printouts (Figure 12). The researcher employed Octoprint, a 3D printing service that utilizes Stereolithography (SLA) 3D printing technology to create a real resin replica from the digital model file. This form of additive manufacturing technology emerged in the 1980s. The Nagoya Municipal Industrial Research Institute's Hideo Kodama devised an additive method for additive manufacturing in 1981 [11]. Kodama developed a product that used UV light to harden polymers and make solid objects, paving the way for Charles Hull's stereolithography, a widely used 3D printing process (SLA). In new and improved stereolithography, the object is printed layer by layer, washed with a solvent, and then hardened by UV light exposure [12]. The 3D print of the dragon is shown in Figure 13.

Figure 13 The 3D print of the dragon

5.4 Bronze Making Process

The researcher tasked Puttakun foundry with the responsibility of casting and patinating the sculpture. Figure 14 shows the wax cast of the dragon head. In Figure 15, the bronze sculpture was created through the lost wax casting method.

Figure 14 The wax cast of the dragon head

Figure 15 The bronze sculpture of the dragon

Figure 16 Three patina choices of the dragon sculpture

Twelve editions were made available in three patina styles: green, gold, and iridescent (Figure 16). All were reserved within a few days after the announcement, and two were purchased by the founders of Adobe Medium. The dragon statues effectively demonstrate the benefits of using virtual reality sculpting as a creative tool to build a complicated sculpture while allowing the artist to work similarly to traditional sculpting techniques.

Discussion

While sculpting with virtual reality is undoubtedly beneficial to artists, knowing which brush to use can enhance the efficiency of sculpting. The clay brush is required as the initial brush since it generates the initial virtual clay. Notably, the clay brush works best when the model's resolution is not excessively dense. At higher resolutions, the clay brush may become extremely sluggish and cause application delays. The move brush is by far the most effective brush, enabling the formation of the basic shape. However, the move brush has the potential to overstretch the surface, causing the affected region to become overly thin, which can result in holes and artifacts. The inflate brush is ideal for detailing the model's surface. The clay and inflate brushes complement the smooth brush beautifully. A frequent approach consisted of adding clay mass with the clay or inflate brushes and then melting the freshly added mass with the smooth brush. While the flatten brush is excellent for creating flat surfaces, the researcher rarely utilized it throughout the experiment due to the organic nature of the sculpted objects, which possessed few flat surfaces. The cut brush was rarely used because the sculpts were the heads, but it is important to note that this brush can be used to break a model into different components. Table 2 highlights the applications, limitations and possible solution of each brush.

Table 2 Virtual reality brushes and their characteristics

VR Brush	Applicable for	Limitations	Possible Solution
Clay brush	Adding sculpt mass	At higher resolution, the Clay brush can be very sluggish	When sculpting in virtual reality, it is best to maintain the resolution at medium. If this issue is encountered, you may reduce the resolution of the model.
Inflate brush	Adding details to the surface at higher resolution	At lower resolution, the Inflate brush may provide unintended effect such as melting away masses of sculpt	Be sure to test out the brushes and see their effect.
Move brush	Blocking out form	It can over stretch the model to be overly thin resulting artifacts such as holes and disconnected surface	The best approach is to gradually use the Move brush instead of trying to it in one stroke.
Flatten brush	Flattening sculpt surface	The brush can affect other parts of the model depending the size if the brush	Make sure you look at the brush cursor since it will show you visually the area that will be affected by the brush.
Swirl brush	Curling parts of the model such as hair	The brush can affect other parts of the model depending the size if the brush	Observe the brush cursor, as it will visually indicate the area that will be affected by the brush.
Cut brush	Separating model parts	The Cut brush can accidentally create undesired cut parts	If it created unintended result, you may use undo button.
Smooth brush	Smoothing out form	At lower resolution, the Smooth brush can destroy primary sculpt form easily	Be sure to test the Smooth brush and its effect.

Prior to sculpting, the sculptor must establish the final size of the artwork in the physical world. The size and shape of the sculpture indicate if an interior framework is required to hold the form together and how much material is required for a certain project. Studio space may also play a role in determining the maximum size of a physical sculpture. Dimensional and gravitational factors can influence the sculpting process. Large sculptures are often cumbersome and difficult to manipulate. Small sculptures can be fairly difficult to construct precisely. The comparison between sculpting in the real world and sculpting in virtual reality is presented in Table 3.

Table 3 Comparative analysis of real-world and virtual reality sculpting

Concerning	Real-World Sculpting	Virtual Reality Sculpting
Sculpture Size	● Must be decided before sculpting. ● Internal structure to hold the sculpture may be needed.	● Can be decided on the fly and can be changed at any given time. ● No need to concern about internal structure
Sculpt Material	● Limited to amount of available sculpting material (Clay)	● Unlimited virtual clay to work with
Studio Space	● Sculpture size is also limited by physical studio space	● Minimal work area for virtual reality sculpting of any size
Weight of the sculpture	● Must consider gravitational force and the sculptor's physical limitations.	● Free of gravity.
Freedom while sculpting	● Within physical limitations	● Can be zoomed in or out to suit the sculptor's needs.

Sculpting in virtual reality, on the other hand, is more forgiving. Because virtual sculptures are weightless, the sculptor is not required to define the sculpture's final dimensions or to design an internal framework. The sculptor can add virtual clay as needed, eliminating the need to stockpile the material. Small portions of the sculpture can be zoomed in on and edited, while bigger forms can be managed when the scene is zoomed out, allowing for creative freedom while working.

Conclusion

Based on the findings of this research, sculpting in virtual reality using Adobe Medium is an approach that has potential as a means of producing sculptures. The researcher integrated virtual reality into the process of sculpting. Within the confines of the time limit of thirty minutes, each head of an ogre was sculpted. This lends credence to the study that compared the lengths of time required for traditional sculpting, digital sculpture, and sculpting in virtual reality. The research concluded that traditional sculpture is 11.26 times slower than digital sculpture, and that virtual reality sculpture is 11.43 times faster than traditional sculpture. [13] Users of Medium's virtual reality sculpting brushes will pick them up fast despite their limited functionality due to the fact that they are similar to their physical counterparts. The fact that the sculptor is not constrained by physical forces such as weight or gravity while working on the sculpture is a significant benefit of the virtual reality sculpting approach. This allows the sculptor to work on the sculpture at any scale. When the view is zoomed out, the primary form of the sculpture may be determined, and when it is zoomed in, precise sculpting of the most minute details can take place. Because of this, the sculptor has an unparalleled amount of freedom, which is something that can only be achieved through virtual reality sculpting. Because of this, the technique can be used for both the concept sculpting and the creation of final artworks. The fact that the virtual reality sculpting approach was able to produce the bronze dragon sculpture that was displayed in this study demonstrates that this method is capable of making sculptures that have intricate components and high detail. This research, which is based on actual practice, shows that sculpting with Adobe Medium can give sculptors unprecedented levels of creative freedom by mimicking real-world tools with virtual reality technology. This, in turn, can help sculptors become more powerful. Sculptors benefit from an experience that is both almost genuine and enhanced thanks to this technology.

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