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The Instantiation Significance of Digital Sculpture: Analysis of the Associated Relationship between Art and Technology

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Abstract: Digital sculpture is the product of the cross-integration of art and technology, and its development is accompanied by the two-way interaction between technological innovation and artistic concepts. Based on this, this paper mainly analyzes the remolding of artistic creation logic by technical tools and the expansion of technical application boundary by artistic expression, and further reveals the dynamic balance relationship between the two in symbiosis, hoping to help understand the accompanying mechanism of art and technology in the digital age.

Keywords: Digital sculpture; Instantiation; Art and technology; Associated relationship

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1. Introduction

"Instantiation" is the process of transforming abstract concepts into concrete forms in the digital context, which has two dimensions in digital sculpture. From the technical level, it is the process of transforming abstract technologies such as codes, algorithms, and modeling tools into visual sculpture forms [1]. On the other hand, the artistic level is a process in which artists' creative and emotional abstract thinking is embodied by digital tools. Traditional sculptures generally rely on physical material characteristics (such as the hardness of stone and the plasticity of soil), so that the creative process is bound to the material properties. As for digital sculpture, it is mainly based on virtual space, and technical tools are an important medium to connect artists' works, which can make the "instantiation" of digital sculpture not only form generation, but also a continuous dialogue between art and technology in the whole creative process [2].

2. The relationship between scientific and technological means and artistic creation

With the vigorous development of digital art, the relationship between scientific and technological means and artistic creation is getting closer, and the interaction between digital sculpture art and instantiation technology

can be said to be a clue to interpret the instantiation significance of digital sculpture. This interaction is not a simple superposition of technologies, but a deeply blended creative ecology, and the artistic conception of digital sculpture constantly pushes the instantiation technology to break through the application boundary [3].

The unique logical rigor of new technology reshapes the artist's creative perspective. The fuzzy judgment based on experience in traditional sculpture is gradually transformed into quantifiable and modifiable, accurate expression with the intervention of digital technology. For example, by capturing every texture on the surface of an object through three-dimensional scanning technology and simulating the dynamic evolution of the form with parametric design software, artists can observe the structural laws of things at the micro level and predict the growth logic of the form at the macro level [4]. This way of observation can not only make the creative process more controllable, but also give birth to artistic forms beyond traditional cognition—those complicated structures that are twisted, folded, and interspersed are almost impossible to realize by hand without the support of digital technology. At the same time, the spirit of scientific rationality has also injected impetus into the innovation of artistic language. In the field of digital sculpture, artists are no longer limited to the inherent properties of physical materials, but can use data as "clay" and algorithms as "carving knives" to explore expressions that are in line with the rhythm of contemporary society [5]. The maturity of instantiation technology makes this exploration have a realistic basis, that is, 3D printing technology can transform virtual models into solid sculptures, while retaining the accuracy of digital design, and it can also give the works a sense of texture through material selection. The appearance of these new techniques is essentially the result of the collision between scientific and technological rationality and artistic sensibility, but the influence of scientific and technological means on artistic creation goes far beyond the tool level and can go deep into the artist's spiritual world and cognitive structure.

In the face of the feast of sculpture art brought by digital technology, we should not only enjoy its visual impact, but also be alert to the creative inertia that may be brought by the "magic" of technology. Only by making scientific rationality always serve the needs of artistic expression can the interaction between digital sculpture and instantiation technology continue to produce valuable artistic achievements.

3. Digital tools remold sculpture instantiation

Today, digital technology has penetrated the art field, and the process of sculpture instantiation is undergoing changes. Digital tools are no longer a supplement to traditional creative means, and can fundamentally reconstruct the sculpture chain. This remolding is not only reflected in the innovation of technical methods, but also extends to the boundary expansion of artistic expression dimensions, which can make sculpture instantiation not limited to physical form shaping, but also become a comprehensive creative behavior that spans virtual and reality [6].

3.1. Modeling technology to break the physical constraints of morphological generation

Three-dimensional modeling technology is becoming more and more mature, such as ZBrush, Blender, Rhino, and other professional software, with the functions of parametric design, subdivision of surfaces, topology optimization, etc., can get rid of the dependence of traditional sculpture on the strength of physical materials and the accuracy of processing tools, and let artists freely explore complex forms beyond the limits of human manual work in virtual space. In terms of parametric design, it is a revolutionary breakthrough. By setting key parameters (such as angle, curvature, density, etc.), the artist drives the form

to automatically adjust a numerical value with the help of an algorithm, and the whole sculpture outline can show a butterfly effect change, and multiple parameters can be superimposed to create an organic form similar to biological growth [7]. This "data-based" creative way not only retains the artist's subjective creativity but also introduces the rigor of mathematical logic, so that the spiral structure full of rhythm can be accurately realized. For example, the artist Michael Hansmeyer's Digital Baroque series generates a virtual sculpture with billions of faces by writing a complex algorithm [8]. The surface folds and depressions are too fine to be completely analyzed with the naked eye. This complex form cannot be designed at the creation stage without relying on parametric modeling technology.

3.2. Virtual rendering expands the instantiation dimension of sensory experience

The instantiation of digital sculpture is not a simple "morphological re-engraving," but a multi-dimensional experience construction including vision, touch, and even dynamic perception. Virtual rendering technology can provide accurate simulation and presentation tools for this multi-dimensional experience. It can make the instantiation of digital sculpture break through the static visual limitations of traditional solid sculpture and extend to richer sensory dimensions such as light-shadow interaction and material simulation. At the level of material and light and shadow simulation, rendering technology has reached the level of confusing the real with the fake. Through a physics-based rendering engine, artists can give texture to virtual sculptures, that is, use software to calculate the rendering effects of different materials under specific light sources according to physical parameters such as light refraction, diffuse reflection, and roughness. In addition, the introduction of dynamic effects can make the digital sculpture instantiate into the "four-dimensional space," and with the help of game engines such as Unity and Unreal, the virtual sculpture can be endowed with motion attributes, so that the sculpture parts can rotate according to a specific trajectory and the shape can be deformed with the audience's interaction [9]. This kind of "dynamic instantiation" can not only break the inherent cognition of "static eternity" of traditional sculpture, but also make the work become the carrier of time flow. For example, some interactive digital sculptures can adjust their shape and color in real time by capturing the audience's body movements. At this time, "instantiation" is no longer a complete state, but a continuously changing process, and audience participation will become a part of the instantiation of works. This kind of sensory experience of instant feedback is difficult to replicate in traditional solid sculptures.

3.3. Cross-dimensional transformation of output technology from virtual to entity

If modeling and rendering technology solves the problem of "virtual birth" of digital sculpture, then the output technology with 3D printing as the core realizes the "cross-dimensional landing" from virtual to entity, which can make the instantiation of digital sculpture have a physical foothold. This transformation is not a simple "copy and paste," but a secondary fusion of technical logic and artistic expression, which not only retains the accuracy of digital design but also gives the unique charm of the material of the work. According to the layered manufacturing principle of 3D printing technology, it fundamentally breaks through the limitations of traditional sculpture technology on materials and structures [10]. Traditional casting and sculpture rely on the ductility and strength of materials, so it is difficult to achieve internal hollowing and complex interspersed structures. However, 3D printing can reproduce every detail in the digital model by stacking materials (plastic, resin, metal, ceramics, and even bio-gel) layer by layer; no matter how complex the shape is, it can be printed as long as it can be designed in virtual space. More importantly, the diversity of materials can also provide artists with many possibilities of expression. The works printed with PLA plastic are light and portable, suitable for outdoor

devices, while the works printed with titanium alloy are durable and can present the cold texture of metal. This kind of "material freedom" can make the instantiation of digital sculpture not only echo the creativity of virtual design, but also generate multiple interactions with the audience through physical materials. For example, the series Phoenix by artist Bing Xu is a classic case of this transformation. The prototype of the work is the industrial waste, such as waste steel, cement blocks, and scaffolding parts, collected by Bing Xu's team at the construction site. After transforming these fragments into digital models through 3D scanning technology, they did not idealize them, but kept the original texture of the waste, and then reconstructed these digital models into two huge phoenixes by metal 3D printing technology. At this time, 3D printing technology is not only a transformation tool, but also a part of the concept of work. Those wastes bearing traces of industrial civilization have been reborn through digital technology reshaping. The sacred image of the phoenix is in sharp contrast with the secular attributes of industrial waste, and the overlapping traces of materials in the process of 3D printing appropriately metaphorize the accumulation and evolution of human civilization. Here, the instantiation process of digital sculpture (from scanning to printing) itself has become the core of artistic narrative, and the technical application has reached a deep resonance with the theme of the work, which has been sublimated into an artistic response to the issues of the times.

4. The boundary extension of creative demand to technology application

4.1. Concept expression promotes personalized development of technical functions

Universal digital tools generally serve the requirements of standardization, and the uniqueness of artistic concepts requires technology to break through the "universal framework." When off-the-shelf software cannot carry specific artistic ideas, artists will take the initiative to become the "reformers" of technology, that is, with the help of customized technical solutions, digital sculptures can be instantiated to accurately respond to the concept expression core. In essence, this process of "making tools for ideas" is the active expansion of technical boundaries by artistic needs. For example, when the artist Rachel Whitereed created the series "Digital Ghosts," she hoped to present the "memory of space" through digital sculpture—that is, to capture the spatial form left after the object was removed. The traditional three-dimensional scanning technology can only record the surface data of the entity, but cannot directly obtain the "void" shape, which conflicts with her artistic concept. For this reason, the Whitereed team cooperated with computer vision experts to develop a customized scanning system. First, the shape of the object itself was scanned by laser, and then the spatial data occupied by it was deduced by an algorithm, and finally the digital model of "negative space" was generated. This technical transformation completely serves the artistic concept of "presenting the invisible," which can make the instantiation of digital sculpture not only the reappearance of form, but also the carrier of time and space memory.

4.2. Aesthetic pursuit of reshaping the value standard of technical evaluation

In the field of digital sculpture, the "advancement" of technology is never equal to the "superiority" of art, and the aesthetic pursuit of art is always reshaping the evaluation system of technology application. Whether a technology is valuable does not depend on how high its parameters are, but on whether it can accurately convey the artist's aesthetic intention and whether it can make the instantiation process and final presentation of digital sculpture form an aesthetic unity. This evaluation standard with "artistic adaptability" as the core can make technical tools return to the essential role of "server." The application of parametric modeling technology can well reflect this point. When some artists indulge in the "extremely complex" form generated by the algorithm and equate technical complexity with artistic value, others actively "simplify technology" to serve specific

aesthetics. For example, the artist Anish Kapoor used the basic NURBS surface modeling tool in the series "Intangible," and only by adjusting several key curve parameters, a concise but full of tension surface shape was generated. He deliberately avoided overly complicated algorithm design and thought that "the beauty of digital sculpture should not be hidden in the dazzling skills of technology, but should be reflected in the occupation and cutting of space by form." Here, the "simplicity" of technology better serves the expression of "pure form aesthetics," which fully proves that the value of technology depends on the fit with artistic pursuit, not its own complexity.

5. Co-evolution of the essential art and technology of the associated relationship

The instantiation process of digital sculpture can reflect the essence of the relationship between art and technology, that is, it is not a one-way subordination of "tools and users," but a symbiotic system. In this system, technology can expand artistic expression, and art can anchor technology, and the two can evolve together in continuous interaction. From the development of art, it is found that its associated relationship with technology has always been the driving force to promote creative innovation. In the Renaissance, the birth of perspective made painting break through the plane limitation, and this artistic language innovation is essentially the application of geometry and optical knowledge in the field of painting. Brunelleschi established the principle of linear perspective through mathematical calculation, and Alberti systematized it into the creative principle in On Painting, which finally enabled artists such as Leonardo da Vinci and Raphael to construct realistic three-dimensional space on canvas. Similarly, the capture of light and shadow by impressionists in the 19th century is inseparable from the progress of optical research. Scientists found that sunlight consists of seven colors, which directly influenced artists such as Monet and Renoir to abandon the traditional inherent color painting method and instead use the juxtaposition of fine color points to simulate light changes. These historical cases prove that every breakthrough in art is closely related to the progress of technology (including scientific knowledge and tools and materials), and the development of technology often obtains new application scenarios because of artistic needs.

Combined with the full text, the essence of digital sculpture in the process of instantiation is the result of a continuous dialogue between art and technology at the intersection of virtual and reality. Technical tools can reshape the logic of sculpture generation and break through the limitations of physics and form; and art needs to guide the application direction of technology. In this relationship, "companion" is not a static balance, but a redefinition of art under technological innovation, and artistic exploration can continue to expand the technological boundary. With the rapid development of new technology, the instantiation of digital sculpture will enter a more complex dimension, but the symbiotic core between them will not change, which can promote sculpture art to new possibilities in the digital age.

Disclosure statement

The author declares no conflict of interest.

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