

Manufacturing of Sculpture in the Digital Age



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1 Introduction: “Lesœuvres acquerront une sorte d’ubiquité”

“Comme l’eau, comme le gaz, comme le courant électrique viennent de loin dans nos demeures [...] ainsi serons-nous alimentés d’images visuelles ou auditives, naissant et s’évanouissant au moindre geste, presque à un signe”¹ (Valéry, 1934, p. 84). Almost 100 years ago, Paul Valéry reflected in his famous essay “La conquête de l’ubiquité” on the immense possibilities that transmissibility granted for “conquering the ubiquity” of artistic work. However, Valéry thought that in the 1920s, one was still quite far from mastering and transmitting “visible phenomena,” unlike the possibilities that already existed then for reproducing music. Nevertheless, he emphatically asserted, referring to the future of the still “rebellious” transmission of “la couleur et le relief,” that “Cela se fera” (Valéry, 1934, p. 86).

Paul Valéry’s prediction instantly evokes the immediacy with which it is now possible to transmit all kinds of information, including the artistic one, as if it were a household supply. With a simple gesture, practically with a signal, it would be possible, in the future envisioned by the French poet, for images or sounds to emerge or fade away, so that artistic expression would be capable of reaching distant destinations instantly. Valéry’s thought revealed a visionary intuition of artistic virtuality.

¹ “Like water, like gas, like electricity come from afar into our homes [...] so will we be supplied with visual or auditory images, arising and vanishing at the slightest gesture, almost at a sign” (Valéry, 1934, p. 84).

Unless otherwise indicated, all translations are our own.

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While it is true that since the 1960s there have been artistic expressions that operate partially or exclusively in the digital realm, either in their creative processes or in their performative aspects (Paul, 2016), during their more than half a century of existence, they have proven to be complementary rather than substitutive to traditional physical art. The uneven reception of digital artworks, from their early and varied manifestations (Paul, 2003) to the controversial non-fungible tokens (NFTs), has led to their expansion in the art market being similarly diverse. The acquisition of tangible artistic creations currently enjoys excellent health despite the immense possibilities offered by purely digital environments.

The exhaustive digitization of three-dimensional objects belonging to cultural heritage through photogrammetry or laser scanning (Argyridou et al., 2023) enables the creation of what Bolton and Cora (2021) refer to as Virtual Equivalents of Real Objects (VEROs). Major museums worldwide have been digitizing the most valuable pieces from their collections at extremely high resolutions for decades (Weber, 2018; Ulaby, 2021; Rühse, 2017; Eveno, 2018) for various purposes. The era in which, with the “slightest gesture,” we can make a digital representation of an artistic piece emerge or fade away instantly is here to stay.

2 From Digital Data to Material Artifacts: “l’étonnant accroissement de nos moyens”²

The open availability of high-resolution digitizations greatly increases the possibilities of manufacturing authentic material clones from digital data. This is among the main reasons why institutions housing works of art are hesitant to share them (Wenman, 2019). The Smithsonian Institution began the massive task of digitizing its collection of 137 million objects in 2009 (Osborn, 2014). However, only a small quantity of them, and not necessarily the most significant ones, are freely accessible.

The economic return that the sale of VEROs in the form of NFTs (Maida, 2022) as well as high-tech reproductions of masterpieces (Holland, 2023; Sansom, 2020) could bring to museum institutions versus the democratizing possibilities entangled by virtual or material enjoyment of artwork, or by the repatriation of heritage in digital or physical formats, is part of a heated debate in the last decade (Alberge, 2013; Samaroudi & Rodríguez Echevarría, 2019).

Despite the ease with which digital data is transmitted and globally multiplied in the present, its materialization into physical objects poses various problems. On one hand, there are ethical-philosophical considerations questioning aspects such as the loss of aura (Benjamin, 1969) or the relative value of an original when copied massively or without rigorous criteria (Krauss, 1981), the control of copyright, and the immense possibilities of distorting original forms through digital techniques.

² “The surprising increase in our means” (Valéry, 1934, p. 83).

The questions regarding the materialization of three-dimensional artistic work from its digital data fundamentally depend on its nature and objectives. The manufacturing of complete replicas that even use the same materials as the original, the creation of facsimiles seeking the appearance of similarity from diverse materials, the production of unpublished works from existing historical data (Merino Gómez et al., 2021), the manufacturing of contemporary art from creations with digital tools, or the low-cost mass production of iconic objects from art history represent areas of three-dimensional production with very diverse consequences.

“The surprising increase in our means” (Valéry, 1934, p. 83) has currently reached micrometric precision in data acquisition capabilities, to the extent that even two-dimensional works, such as serigraphs, frescoes, or paintings, can be treated as three-dimensional, almost sculptural objects (Bayod Lucini, 2022). However, when it comes to creating an artistic clone based on what data acquisition tools and software can store and process, technical means still suffer from limitations. Even in our technological present, with a wide catalog of highly roboticized manufacturing tools, with micrometric scopes and enormous programming possibilities, the manual component remains necessary, for the time being, in the production of high-quality replicas and facsimiles.

On the other hand, the possibilities that 3D digital printing currently offers for the serial manufacturing of artistic reproductions are unprecedented. When pop art emerged in the late 1950s, reclaiming connections between artistic work and serial production through pieces that criticized or exalted mass production and consumption (Madoff, 1997), no one suspected the revolution that 3D digital reproducibility would cause in the art world in just a few decades.

The instantaneous availability, despite restrictions often imposed by owners or exhibiting institutions (Sansom, 2021), of digitized data and the widespread use of 3D printing technology offer new perspectives in the large-scale physical dissemination of models, bringing us to some extent closer to the kind of teleportation envisioned by Valéry when he referred to the possibility of “transporting or reconstituting in any place the system of sensations [...] provided anywhere by any object or any event”³ (Valéry, 1934, p. 84).

3 The Mass Production of Three-Dimensional Artifacts in Artisanal and Artistic Contexts

The materialization of three-dimensional virtual data through highly sophisticated tools renews, improves, and multiplies the options for mass production compared to the possibilities that existed just over a century ago. During the Second Industrial Revolution (Hounshell, 1985), mass production systems became widespread,

³ “[...] transporter ou reconstituer en tout lieu le système de sensations [...] que dispense en un lieu quelconque un objet ou un événement quelconque” (Valéry, 1934, p. 84).

particularly efficient for manufacturing identical objects. Assembly lines and the successive automation of processes contributed to modifying the social and economic landscape globally. The possibilities of producing thousands of copies of virtually any object faced fierce opposition in its early stages from those involved in traditional arts. The anti-modern desire to return to pre-industrial modes of production (Stankiewicz, 1992), however, contradicted some of the mass production systems that have characterized a significant part of artisanal and artistic production throughout history.

Repetitive manufacturing processes, traditionally employed in the production of practical objects such as amphorae, lamps, tiles, or bricks, were also applied to the methods of producing less utilitarian and more artistic items. Thus, in antiquity, the serial production of votive figurines destined for offerings in sanctuaries to express gratitude and piety or seek favors from the gods was common. Despite the exceptional nature of devotional objects and their transcendent function, their manufacturing processes were analogous to those of more mundane items. There is evidence that, in some cases, when it came to *terracotta* images, they were manufactured in the same facilities where everyday utensils like household pottery were produced (Barletta, 2006).

The serial production of small-scale bronzes around 900 B.C. in the vicinity of the sanctuary of Olympia (Mattusch, 2006), the mass production of Egyptian votive bronze statuettes dating from the seventh century B.C. onwards (Leahy, 1988), the small *terracotta* figures molded in Tanagra (Greece) from 500 B.C. to 200 B.C. (Higgins, 1986, p. 66), or the affordable *terracottas* of Attis, mass produced in connection with the cult of the goddess Cybele in the second century B.C. (Turcan, 1997, pp. 40–41), are just a few examples that demonstrate how, since antiquity, there has been a close relationship between serialization and the production of similar products in realms that transcend the mere functionality of the pieces.

The mass serialization of figurines in archaic cults throughout the Mediterranean would gradually be replaced in the Christian period by the increasingly unique production of devotional objects. In artifacts such as altarpieces, funerary sculpture, or processional items, uniqueness will become a parameter adding value to manufacturing, and production will be subordinated to specific demand. Such productions are within the reach of wealthy individuals or collectives that can afford unique commissions through collaborative cost-sharing.

However, in more popular aspects of Christian culture, small-scale widely distributed religious products continue to be made available to the public, whose religious functions little differ from those intended in antiquity (Talloen, 2011, p. 593). The mass production of reliquaries in various materials such as plaster or *terracotta* ensured their availability in the market at affordable prices (Renkin, 2021). The production in multiple copies of small figurines of saints for small altars, domestic or urban, the mass production of figurines linked to Marian worship sites, or the production of all kinds of votive offerings in wax, plaster, plastic, silver, etc., depicting diseased body parts, whose healing is prayed for or thanked for (Weinyrb, 2018) are many other objects that have been manufactured, marketed, and acquired on various scales from the Middle Ages to the present moment (Holmes, 2009).

Beyond devotional uses, from the Renaissance onward, decorative objects began to be integrated into the domestic setting. The *Dovizie* from the workshop of the Florentine Giovanni dellaRobbia (Randolph, 2002), and from the eighteenth century onward, the renowned figures from the Ginori workshops, or the highly prized decorative vases from Josiah Wedgwood (Holt & Popp, 2016), in the latter half of the same century, straddle the line between mass production and the creation of similar pieces with some variations.

No movement had more impact than the Arts and Crafts movement in challenging the boundaries between artisanal craftsmanship and industrial production in the late nineteenth century (Boris, 1986). During the same period, the dissemination of small-scale domestic sculpture, produced through mold repetition, gradually moved away from the perception of luxury from previous centuries and began entering homes. At the same time, it sparked controversies about the originality and authorship of such manufactures (Gosse, 1895).

Additionally, other aspects related to specialization and the loss of identity inherent in mass production processes (Luckman, 2012), or the decline in value that multiplication bestows upon the artwork, would extend into theoretical debates throughout the twentieth century (McDonald, 2004; Benjamin, 1969; Siebenbrodt & Schöbe, 2009; Mag Uidhir, 2013). These debates would be renewed with the advent of digital technologies in the twenty-first century. The traditional perception that industrial multiplication is contrary to the singularity of the artwork is criticized but also fades through the serialized productions of many artists in the second half of the twentieth century. Works by artists like Sol LeWitt, Juan Muñoz, or Jeff Koons leverage the resources that mass production offers to create “new originalities” in the realm of artistic sculpture.

4 Hoc Opus Hic Labor: The Difficult Task of Producing Artistic Three-Dimensional Manufactures

The intrinsic difficulties of reproducing visual information have been evident since the early days of printing (Bland, 1974). Woodcuts, engravings, or lithographs are based on the principles of laborious incision on rigid surfaces to allow for subsequent serial printing. It would be necessary to wait until the late nineteenth century, with the advent of photomechanical reproduction processes (Griffiths, 1996) and their subsequent refinement throughout the twentieth century, to observe the definitive democratization in the reception of visual arts. Mechanization in image reproduction would contribute not only to the dissemination and fame of many paintings and photographs now globally recognized (Beegan, 2007) but also to the knowledge, albeit in two-dimensional form, of the masterpieces of sculpture.

Nevertheless, the “conquest of ubiquity” in terms analogous to those achieved for the dissemination of two-dimensional images or music still had to wait for three-dimensional objects. Although, as mentioned in the previous section, the almost

industrial production of volumetric pieces has never been foreign to artistic contexts, the intrinsic difficulties in their manufacture, especially in larger-scale objects, have always limited them to a small number of copies and an eminently affluent audience.

The levels of industrialization reached by sculpture production in Italy in the second half of the eighteenth century are well-known. Renowned workshops received commissions from all over Europe (Honour, 1972b), and the speed of production had to adapt to the growing demand. Manufactories, many of them producing copies of classical sculptures from the workshops of Bartolomeo Cavaceppi and Carlo Albacini (Howard, 1991), had extended their reputation to England, Germany, France, and Spain (Rotili, 2023). The serial characteristics achieved in the three-dimensional production of the Piranesi workshop under the direction of his son Francesco (Bosso, 2006) satisfied, for a time, the extensive demand for artistic pieces from Grand Tour travelers.

Despite the international success of Antonio Canova, spreading to the far reaches of Europe and even reaching the United States (Johns, 1998), his methods of sculptural manufacturing, incorporating components of mass production, were widely criticized by prominent figures of his time (Honour, 1972a). Stendhal, despite holding an excellent opinion of the *Veneto* sculptor, stating that he was “too great not to have opposition”⁴ (Stendhal, 1818, p. 139), observed, however, that his works were the result of the exact copying work done by his assistants in marble based on plaster models:

Ses gens jettent du plâtre sur cette terre [the clay on which Canova had modeled his sculpture], font un moule, et reproduisent la statue, en plâtre. Canova la perfectionne, ses gens font une copie exacte de la statue de plâtre, en marbre. On transporte le marbre dans l’atelier particulier de Canova, qu’il achève. Voilà son seul travail sur le marbre. Il se réduit à quelques coups de lime.⁵ (Stendhal, 1818, p. 139)

The assembly line manufacturing of Canova’s work allowed him to produce more than 350 sculptures between 1769 and 1822 (Pavanello, 1976). This substantial production undoubtedly contributed to a literal globalization of the Canovian sculptural phenomenon. However, it also garnered numerous criticisms, and the production from his workshop almost immediately ceased after his death, despite the substantial delegation of the process to a significant number of assistants (Fernow, 1806, pp. 102–103). Four centuries earlier, Michelangelo, using more direct and less sophisticated methods, produced around 60 sculptures, many of them unfinished (Russoli, 1963), despite his sculptor career extending over 75 years (Hartt, 1968) and his quick stone carving skills. Blaise de Vigenère recounts how he had the

⁴ “trop grand pour qu’il n’y ait pas un parti contraire” (Stendhal, 1818, p. 139).

⁵ “His people cast plaster on this soil [the clay on which Canova had modeled his sculpture], create a mold, and reproduce the statue in plaster. Canova perfects it, and his people make an exact copy of the plaster statue in marble. The marble is transported to Canova’s private studio, where he completes it. That is his only work on the marble. It comes down to a few strokes of the file” (Stendhal, 1818, p. 139).

opportunity to witness the extremely rapid and seemingly tireless way in which Michelangelo worked:

[...] je puis dire auoirveu Michel l'Ange bien que aagé de plus de 60 ans, & encore non des plus robustes abattre plus d'escailles d'un tres dur marbre en un quart d'heure, que trois jeunes tailleurs de pierre n'eussent peu faire en trois ou quatre, chose presque incroyable qui ne le verroit: & y alloit d'une telle impetuosit& furie, que je pensois que tout l'ouvrage deust aller en piéces, abattant par terre d'un seul coup de gros morceaux de trois ou quatre doigts d'espoisseur, si ric à ric de sa marque qué s'il eust passé outre tant soit peu plus qu'il ne falloît, il y avoit danger de perdre tout, parce que cela ne se peut plus réparer par après, nyreplastrer comme les images d'argille, ou de stucq.⁶ (Vigenère, 1615, p. 855)

The quantitative difference in the production of the two most celebrated sculptors of their respective eras owes much to the efficiency of Canova's serialized method, timely implemented to meet demand, compared to the direct force employed by "le divine mani di Michelagnolo"⁷ (Vasari, 1568, p. 725), even considering the collaborative processes of traditional sculpture workshops.

Despite the notable leap in manufacturing methods during the Neoclassical period compared to the Renaissance, both serialized production and the singular creation of stone sculptures still required significant effort. Antonio Canova recounts in his Roman diary that on June 15, 1780 "nello studio del signor Carlo Albagini [...] vidimo molti giovani che stavano ristaurando delle statue, uno delli detti faceva la copia della testa di Lucio Vero di casa Borghese e mi dice che gli aveva lavorato quatordecim mesi nella sopradetta testa e che ci mancavano ancora cinque mesi di lavoro per terminarla"⁸ (Canova, 1780). Indeed, despite the organization of work and the considerable manufacturing capacity of Albacini's workshop, the effort involved in three-dimensional production is evident, even when it came to reproductions.

While it was possible to improve subtractive processes in stone manufacturing during the eighteenth century, the challenges posed by additive methods, such as bronze casting, show that the methodological distance from traditional processes is practically nonexistent. The duration of work to sculpt large bronze pieces is measured in years, if not decades. Pliny the Elder mentions the 12 years needed to cast the Colossus of Rhodes (Pliny, 1961) in the early third century B.C. Twenty years were required for the casting and completion of the equestrian sculpture of

⁶ "I can say that I have seen Michelangelo though over 60 years old and not among the most robust, chip off more scales from very hard marble in a quarter of an hour than three young stonecutters could do in three or four, an almost unbelievable feat if one did not witness it. He went about it with such impetuosity and fury that I thought the entire work would shatter. With a single stroke, he would bring down large pieces three or four fingers thick to the ground. If he had continued even a little beyond what was necessary, there was a danger of losing everything, because it could not be repaired afterward or patched up like clay or stucco images" (Vigenère, 1615, p. 855).

⁷ "Michelangelo's divine hands" (Vasari, 1568, p. 725).

⁸ "In Mr. Carlo Albagini's studio, where we saw many young people who were restoring statues, one of them was making a copy of the head of Lucius Verus from the Borghese house. He told me that he had been working for fourteen months on the aforementioned head and that there were still five months of work remaining to complete it."

Louis XV le Bien-Aimé, conceived by Bouchardon (McClellan, 2000; Mariette, 1768) in the second half of the eighteenth century, and almost 20 years were needed for Clemente Papi to cast a bronze copy of Michelangelo's David (Videtta, 2017) a hundred years later. Canova himself, in a letter to Quatremère de Quincy on January 17, 1808, asserted his right to live in peace, refusing to deal with the bronze casting of Napoleon's equestrian sculpture on behalf of Joseph Bonaparte: "Io non voglio impicciarmi per nulla nell'affari della fusione in bronzo della statua equestre. Voglio soltanto far i modelli, dirigere la cera, vigilar al ritocco del bronzo; ma voglio viver tranquillo, non voglio impicci" (Quatremère de Quincy, 1834, p. 372).

5 Il a ôté tout ce qui est physiquement pénible:⁹ The Three-Dimensional Artistic Manufacturing in the Digital Era

In his eagerness to get rid himself of the physical work associated with sculpture, Canova maintained five or six rooms in his "officina statuaria" on via delle Colonnate in Rome, where his assistants worked, and an "atelier particulier," in which "Il a ôté tout ce qui est physiquement pénible" (Stendhal, 1955, p. 1146). The arduous ("pénibles") parts of the manufacturing processes referred to by Stendhal would undergo few changes throughout the nineteenth and twentieth centuries. To witness the true revolution, both in data capture and translation methods and in sculptural operations, it would be necessary to wait for digital data acquisition techniques and advances in software-directed robotization, which would not develop until the late twentieth and early twenty-first centuries.

In terms of data capture, digital photogrammetry and laser scanning techniques definitively surpass the age-old contact-based methods. The printing of negative molds of three-dimensional objects on various plastic materials (Sargentis, et al., 2022) or point-based techniques for reproductions at the same or different scales, using pantographs and similar devices (Payne, 2023), will give way, from the late twentieth century onwards, to non-invasive methods where physical contact with the models to be translated or copied is no longer necessary.

Regarding the manufacturing process itself, in the context of the automation of industrial processes in the late nineteenth and early twentieth centuries, there was also room for "sculpturing machines" (Dunstan, 2014). Although their mechanical principles were practically the same as those of the earlier pantographs, their power, capable of "pass over the marble away like cheese" (Scientific American, 1903, p. 260), foreshadowed a future free from the physical hardships that had always been associated with three-dimensional manufacturing.

Whether the history of sculpture, beyond the creative genius, demonstrates its collective nature and the importance of delegating the hardest work to apprentices

⁹ "He has removed everything that is physically painful" (Stendhal, 1955, p. 1146).

and assistants, never has the process of delegation in manufacturing and the liberation from physical labor been more evident than in the present. In both the realm of additive methods, with the revolution of 3D printers, and subtractive methods, the landscape for the manufacturing of three-dimensional artistic works is changing rapidly.

The design of robots specifically crafted for sculpture, programmable with various types of software (Xuejuan et al., 2007; Lu et al., 2020), and equipped with high-precision tools is already capable of emulating the most intricate traditional manufacturing on moderately hard stone materials like Carrara marble in the present day (Bubola, 2021). Progress in three-dimensional production of metallic artistic objects is also rapidly expanding. The ability to melt metal powders of different compositions using high-power lasers is paving the way for the creation of works materialized in metal, representing an unprecedented qualitative leap in 3D metal printing (Eom et al., 2021).

Regardless of the manufacturing processes available at the present moment, manual finishing is still employed to eliminate machining traces, refine details, or give finished pieces a patina. These artisanal operations represent the last stronghold of human intervention, which will soon be more symbolic than necessary.

6 Conclusions

The “ultima mano”¹⁰ (Cicognara, 1823, pág. 253), with which Canova pledged to complete the sculptures from his workshop (Ferando, 2015), will consist of a symbolic way of imparting to the artwork “quell’alito di vita, quel moto, e quasi [...] quella parola”¹¹ (Teotochi Albrizzi & Cicognara, 1824, p. 101) that seemed to animate the sculptures of the Venetian artist. The mythology surrounding three-dimensional works, especially anthropomorphic ones, appears to demand the presence of Hephaestus, Pygmalion, or Pyrrha, capable of infusing them with their own vital nature. The highest praise that could be bestowed upon a sculptural creation in the traditional artistic conception was to be possessed by life itself: “La Notte, che tu vedi in sì dolci atti dormir, fu da uno Angelo scolpita in questo sasso; e perché dorme, ha vita. Destala se no’l credi, e parleratti”¹² sang an anonymous praise in the time of Michelangelo (Vasari, 1568, p. 741).

The theoretical debates that began in the late nineteenth century would ultimately relegate the realism of figurative representations, both in two and three dimensions,

¹⁰ “The finishing hand” (Cicognara, 1823, p. 253).

¹¹ “That breath of life, that movement, and almost [...] that word” (Teotochi Albrizzi & Cicognara, 1824, p. 101).

¹² “The Night, whom you see sleeping in such sweet poses, was carved from this stone by an Angel; and because she sleeps, she has life. Awaken her, if you do not believe, and she will speak to you” (Vasari, 1568, p. 741).

to just another feature of artistic manufacturing. The new parameters introduced by digital models and total mechanization with results indistinguishable from traditional methods broaden the *vexata quaestio* of the necessity of human intervention in artistic manufacturing processes.

Although the trend towards the digitization and total robotization of three-dimensional art could portend effects analogous to what photography had on the two-dimensional, the truth is that episodes in the transformation of sculptural currents already occurred in parallel within the realm of twentieth-century avant-gardes.

The attention that these seemingly surpassed issues attract in the art world becomes evident when authors like Anish Kapoor (Clouston & Sayer, 2016) or Maurizio Cattelan (Lydiate, 2022) openly declare who they entrust with the manufacturing of their works, while others demand that the companies keep their identities secret (Bubola, 2021). The idea of the sculptor as someone who “nel fare la sua opera fa per forza di braccia e di percussione a consumare il marmo, od altra pietra soverchia, ch’eccede la figura che dentro a quella si rinchiede, con esercizio meccanicissimo, accompagnato spesse volte da gran sudore”¹³ that Leonardo (1498, p. 32) almost caricatured in the Quattrocento and which Harriet Hosmer (1864, p. 734) lamented in the nineteenth century somehow persists in the imaginary of sculptural workmanship. The reluctance of some artists to reveal the manufacturing companies and the means by which they execute their pieces undoubtedly conceals the romantic ideal of the creator’s physical touch in the artwork even in the digital age.

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¹³ “In creating his work, he employs the strength of his arms and percussione, to consume the marble, or another excessive stone, that exceeds the figure enclosed within it, with a very mechanical exercise, often accompanied by great sweat” (Leonardo, 1498, p. 32).

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