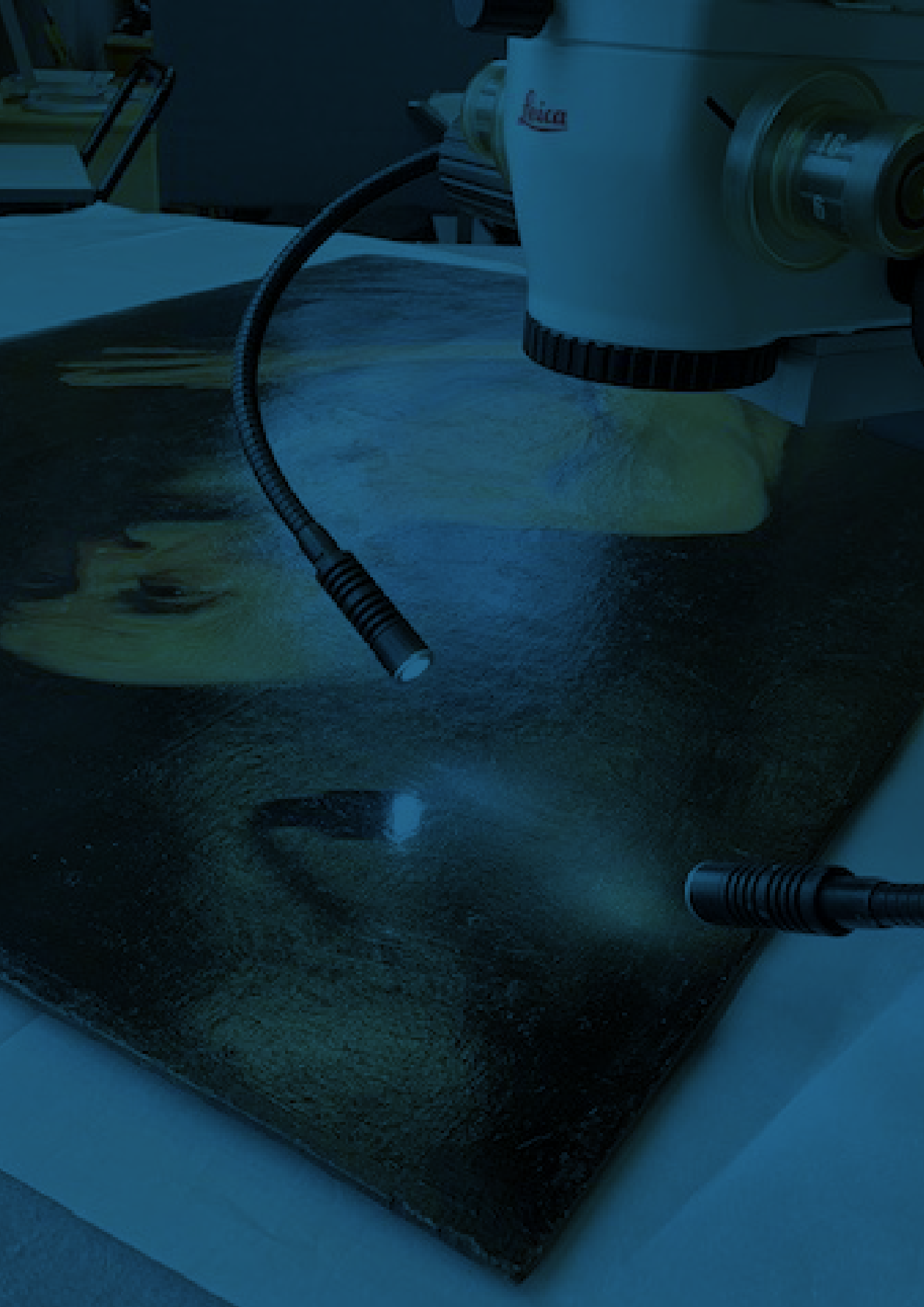
Leica

PEER-REVIEWED ARTICLE

THE EXPANDED PAINTING: THE VISUAL CULTURE OF PAINTING IN THE DIGITAL AGE

LISBET TARP

ABSTRACT | Digital reproductions of artifacts are utilized in an increasing range of professional work with cultural heritage. Because paintings are relatively easy to capture and transfer to the digital realm, an increasing number of them are now being photographed and made accessible in databases. However, as this article points out, paintings can be used as a point of departure for a wide range of digitally-based copies of their material and visual components, a phenomenon described as the visual culture of painting. By employing Greimas' square, this article explores how computer-aided reproductions of paintings can be differentiated, distributed, and described according to their basic formal qualities from digital photography and analytical imaging to 3D-printed versions. The square also enables a description of formal features and outlines the limitations of each type of reproduction by placing painting in relation to its historical counterpart, sculpture. In this mapping, tensions between opposites appear, including the virtual versus the material, two- versus three-dimensionality, surface versus matter, and the multifaceted struggle to cope with invisible structures. These issues have been illustrated and negotiated for hundreds of years in the practice of making and appreciating paintings, but this article reframes them for the digital realm.

KEYWORDS | painting, analytical imaging, photography, image theory, materiality

Introduction

Imposing Greimas' square on the concept of painting allows for the mapping and description of digitally-based copies of paintings prevalent today. By expanding painting as a category in deliberate contrast to sculpture, this article illustrates ways in which copies translate and embody the properties of paintings in both virtual and material versions. Despite differences in their genesis, multiple types of copies can be sorted into groups of images that derive from paintings. In this way, the digitally-based reproductions illustrate what can be described as a visual culture of painting. This phrase reflects the fact that there is an increasing number of digitally-based images that surround and extend individual paintings in the digital realm. In various ways, the visual culture of painting seems to both suspend and release the tension existing between reproduced objects and their digital copies. Because of this, the properties of each reproduction and its representational relation to the artifact can be applied to research contexts.

The first part of this article examines the backdrop for expanding the field of painting into a semiotic and visual domain. This is followed by a historical framing of painting and sculpture as a pair of concepts. Then, four different kinds of digitally-based reproductions of paintings are mapped out in Greimas' semiotic square. In this process, digital photography (visible light), analytical imaging, 3D printing, and virtual 3D copies of paintings are outlined. As an example of analytical imaging, case material from my research group project Digital Art History: Rediscovering the Painting is presented, while further examples are taken from other projects.[1] The article concludes with a few thoughts on how the visual culture of painting can be theoretically framed with the concept of "thickets."

Expanding a Field

What does it mean to expand the notion of painting? The literature on how paintings are expanded or extended often deals with artistic experiments related to Modernism and its counter-reactions.[2] In this context, artists challenged the definition of painting as a depiction on a flat surface by developing its format and extending it physically with sculptural elements. The formal and theoretical implications of these experiments have been dealt with extensively in

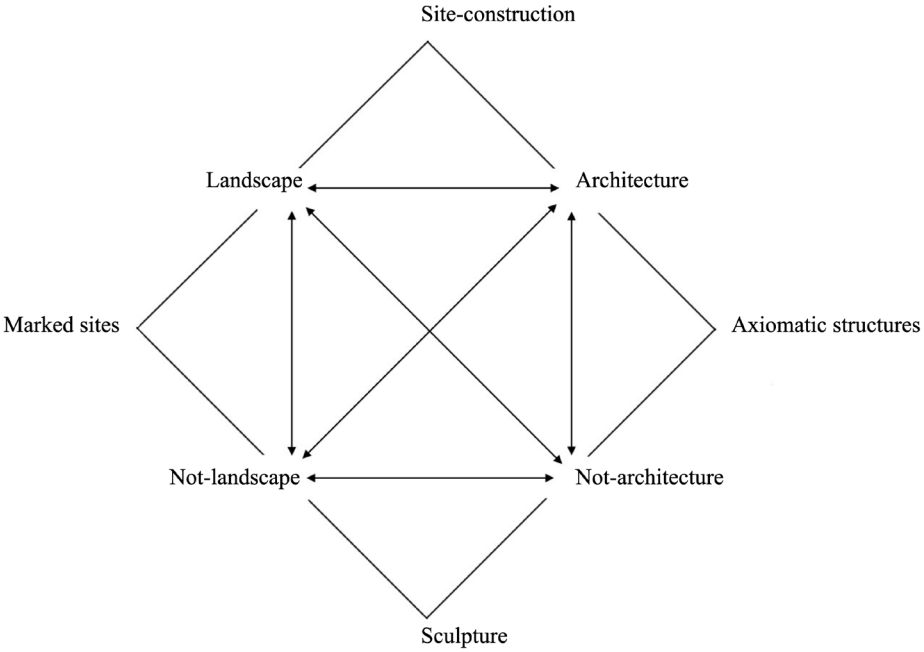

Figure 1. Rosalind Krauss' sculpture in the expanded field, Krauss 1979, p. 37.

art history. In this article, however, the notion of expanding painting is different. Instead, I question how a painting's presence as an artifact is developed with digital means and how we grasp this expansion conceptually. Even though Greimas' square is rooted in structuralism, it is still useful to explain how digitally-aided appearances of paintings can be characterized. However, the difference between applying the square to a conceptual pair of oppositions in semiotics and to a case study in visual arts calls for further explanation.

The title of this article is inspired by the often-quoted article, "Sculpture in the Expanded Field," by art historian Rosalind Krauss.[3] By mapping sets of relations in a square, Krauss differentiates between formal qualities of artworks that grew out of mid-twentieth century experiments with spatial construction. In this way, Krauss famously configures the concept of sculpture within a wider field of artistic expression that departs from notions of landscape, architecture, and their counterparts, not-landscape and not-architecture (fig. 1). The concepts of site constructions, axiomatic structures, sculpture, and marked sites are thus established in relation to their formal similarity and dissimilarity to the two central concepts of the square to which they are attached. This means, for instance, that the so-called axiomatic structures resemble architecture, while also displaying formal features that distinguish the artistic construction from this category. Likewise, marked sites have features relating to both landscapes and not-landscapes. In this schema, sculpture can be viewed as the most marginalized concept because it is defined as a negation of both landscape and architecture.[4] In relation to this article, it is worth noticing that this way of defining relationships in a selected cultural field stimulates conceptual development, a reflection on implicit values, and an awareness of the effects, functions, and limitations of each kind of artistic outcome.

In establishing her expanded field, Krauss refers to the Piaget group, the semiotic square developed by Algirdas Julien Greimas and François Rastier, and the Klein Group.[5] The semiotic square and the Klein Group are embedded in the logics of language and mathematics respectively, while Jean Piaget's configuration is situated in psychology. By adapting the square to a visual cultural field, Krauss introduces a new modality and a setting that implicates yet another kind of logic. This article shares that purpose to describe diverse visual material. In my case, however, it

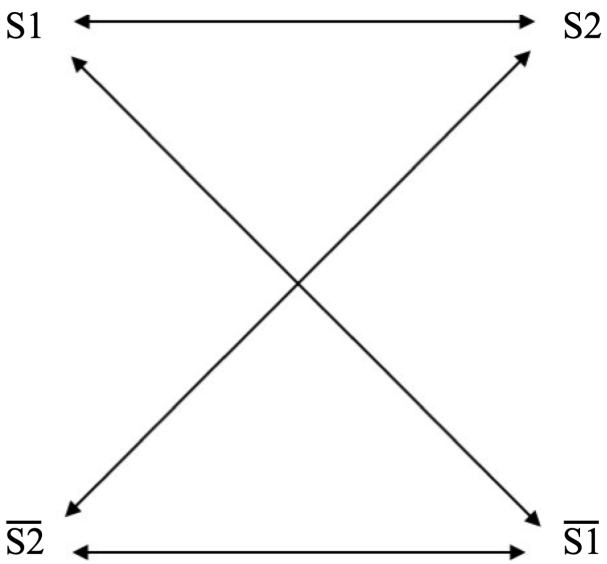

Figure 2. Greimas' square. Greimas and Rastier, 1968, p. 88.

was not useful to imitate Krauss' adaptation of the square because she alters the positions in the negated row (-S1 and -S2).[6] Consequently, her application collapses as a semantic category according to Greimas and Rastier, because S1 has to implicate -S2 and S2 has to implicate -S1.[7] Since Krauss has inspired many people working with culture and artifacts to utilize the square and thus analytically unfold and explore a given opposition, the negated row often imitates her composition. However, as will be shown later, Greimas' square is a more productive point of departure that allows for a meaningful distribution of the digitally-based images targeted here. In order to explain this point of departure, Greimas' square is outlined in the following:

Greimas' square is based on a defined set of opposing terms (S1 and S2). From these terms, related concepts can be unfolded and mapped, thus rendering visible certain values and meanings (fig. 2). Greimas developed this idea during the structuralism wave of the mid-twentieth century, fine-tuning it in his article with François Rastier, "On the Constraints of the Semiotic Square," in 1968.[8] To construct a square according to Greimas, one begins with a term and then defines an opposing term, the so-called complex axis, S1 and S2. A frequent example of this is life (S1) versus death (S2). The next step is to define the negated terms, -S1 and -S2, the neutral axis. In the life/death example this is not-life (-S1) and not-death (-S2). Imagining what not-life and not-death may be is the first step in adapting the square to suit a specific cultural context, for instance in interpreting a mythological narrative in a story or examining the way in which a taboo is established in a culture.[9] In this way, the semiotic square can be used to expose the logic of a cultural set of values that may at first appear casual, accidental, or even irrational. Additionally, mapping these (sometimes) irreconcilable and mutually exclusive concepts leads to identifying dependencies between these concepts as well as implicit consequences in the cultural context.[10]

As previously mentioned, Greimas and Rastier state that in order to illustrate a semantic category, -S2 has to implicate S1 and -S1 has to implicate S2.[11] In the example above, this means that life (S1) is implicated in the hypernym not-death (-S2). Not all opposing terms may work in the semiotic square, and some applications fail to make logical sense. The fact that the adaptations do not always work indicates that establishing a semiotic square involves an act of interpretation. When employing this model in a cultural setting, the values and definitions are not fixed but are embedded in changing usage and cultural contexts and depend on the interpreter's bias. This application process thus differs fundamentally from a mathematical context like the Klein Group.

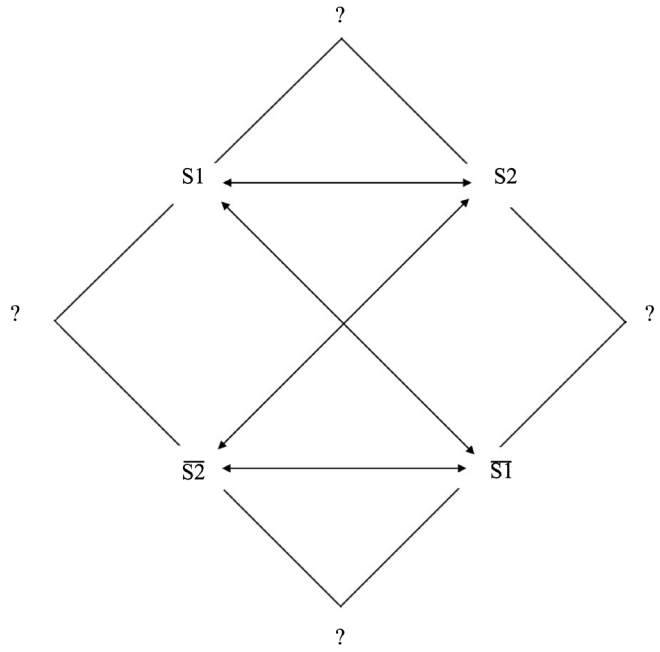

Figure 3. Greimas' square with adaptations. Adapted by Fredric Jameson in The Political Unconscious, 1981.

For the purpose of this article, the external nodes S3, S4, S5, and S6 attract the greatest interest (fig. 3). Although Greimas lightly touched upon these nodes in his conception of the semiotic square, they were further developed by the literary critic and philosopher Fredric Jameson.[12] In his application of the square, Jameson identifies the external nodes, also called compound terms or meta terms, as points that reveal the structures of power relations. In the following, it becomes clear that conflicting but mutually dependent formal qualities of painting as a medium are exposed in the external nodes. This has to do with painting being valued as a depiction with a story, while it also has a physical placeholder. The digital remediations expose that the means of painting often urge that we 'look through' its material carrier. In this way, the external nodes amplify the tension residing in the painting's sculptural being that can go against the illusion or supposed message.

Like Krauss' approach to her analytical material, this article recognizes formal differences between specific artifacts; in my case, the focus is on how paintings are developed and perceived when digitally-mediated and distributed. Since the variety of expressions is great but interconnected through the attachment to painting, the semiotic square is a productive tool to apply this schema and map analytical observations; the process for which is illustrated with examples below. Still, the square should be understood as a point of departure. It is important to retain an awareness of the unstable meaning of the concepts involved, as well as the valorization inherent in the process of defining nodes. This method involves an act of interpretation that balances the relation between words and visual appearances.

Expanding the Painting in the Digital Realm

The challenge of the semiotic square is finding a set of terms whose relations lead to a relevant mapping. Attempts to expand concepts often result in an empty node or two nodes that overlap in meaning. On other occasions, the result is too obvious and does not generate or highlight any interesting aspects of the chosen concepts. In my own application, I follow Greimas and Rastier in using the complex axis (S1 – S2) as a starting point. This positions

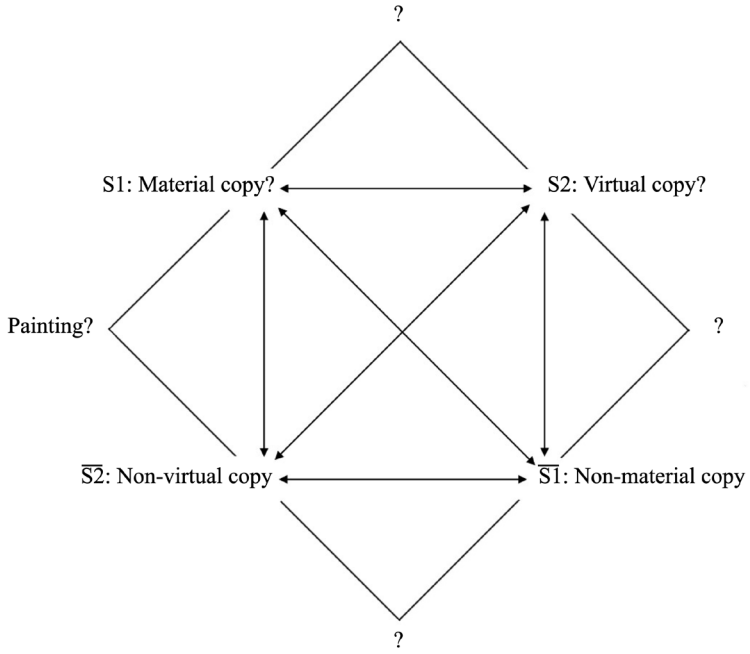

Figure 4. Greimas' square applied to painting and its reproductions. Illustrated by the author.

the concept of painting as S1 in the square. The following step was then to choose an opposite term to painting (S2). Initially, it seemed obvious to juxtapose the difference between the artifact and its virtual versions, thus privileging the classical opposition between original and copy (fig. 4). This choice would develop Krauss' brief comment that the painting could be expanded in relation to the concepts of uniqueness and reproducibility.[13] In this mapping, S3 would denote painted copies and S6 would denote graphic reproductions. 3D printed paintings that are subsequently painted would be placed in the node S4, while S5 would represent the entire group of digital images of paintings (digital photography, analytical imaging, and virtual 3D representations of paintings).

This approach may signal that the copies (digital and analogue) are poor reductions of the painting and consequently emphasize the importance of the artifact's authenticity. As explained below, a computer-based copy of a painting does not necessarily lead to a reduction of the (visual) information available to our senses. Therefore, though it might be useful to unfold the painting's relation to uniqueness and reproducibility, it does not clarify the different characteristics of digitally-based reproductions properly. Furthermore, this mapping only establishes two different groups (S4 and S5). A further distinction based on the visual and physical properties of the copies is needed.

When expanding the presence of paintings in the digital field, there are many options to consider. The digital field could reference both digital copies and physical copies based on digital techniques such as 3D printing. Hence, some copies inhabit both the physical and virtual realm, making the opposition between virtual and material more productive as a secondary feature in the square. Even so, the primary opposition to painting must be established and its oppositional term rethought.

Painting and Sculpture as Rivals

Even though tension between the physical and the virtual had to be integrated into my square, a more flexible distribution of the properties that cross borders between digital, virtual, 2D, 3D, materiality, visibility and non-visibility was desirable. This drew my attention to similar issues that have been addressed in the past. As acknowledged by other scholars of early modern European art history, previous visual and

theoretical issues regarding images reemerge in the digital field, particularly around the question of representation.[14] For instance, how can one show and deliver what is not present as if it was present, surpass the original, or produce or alter a copy? Theoretical issues also emerge when images could be grasped both as artifacts and as virtual objects in the broadest sense. The making and judging of representation is ambiguous and deeply rooted in values of copies and copy-making that have oscillated significantly in Western history. At the core of important philosophical and religious questions throughout history is whether imitations or replications of terrestrial, sublunary, or imaginary phenomena are valid or appropriate. In these quests, painting has played a part in the discourse.

In Western art history, painting has been traditionally defined in opposition to sculpture both as a medium and as a means of expression. The famous Renaissance dispute, known as the paragone, determined some of the essential traits of expressing ideas in two or three dimensions and articulated how to activate a real or imagined space for a depiction to be recognized or experienced animated and lifelike.[15] This is a far-reaching subject, but in short, sculpture as a medium masters space, giving physical matter and shape to the depiction. Painting, for its part, delivers a more complex expression of the depicted scenery because it operates within an imagined space, where natural laws can be suspended. In this way, painting was celebrated for making several angles of a phenomenon perceivable at the same time and showing convincing illusionistic simulations that defy the opacity of the painting's surface.

In the Renaissance understanding, painting's materiality was occasionally addressed in relation to its manifestation of subtle or dramatic visual references, indicating the medium's paradoxical position as both illusion and presence. Embedded in the paragone disputes are statements that relate to both painting and sculpture: for instance, scholars discussed the act of inspiriting or infusing an artifact with life, the ambition of surpassing nature in art, and displaying the skills and qualities of the maker. Ideas related to copying the world's phenomena in reliable and meaningful ways were embedded in artistic experiments that involved manipulating matter and surfaces and incorporating interactive elements, ephemeral effects, and movement. In part, these ambitions take on new forms in the digital sphere, where artifacts are copied and reproduced in multiple ways and similarly imbued with different values. One of the central issues in the production of augmented and virtual reality, for example, involves optimizing the formal features that underpin the experience of lifelikeness in a broad sense. Moreover, when it comes to representing artifacts digitally, the question is often how to make artifacts appear as if they are present. It is an ongoing challenge to translate the properties of artifacts digitally and to produce accessible, proper, and enriching experiences for research, learning, or entertainment.

Additionally, it is pertinent to relativize the idea of the "good copy" and instead ask: a good copy for what purpose?[16] A wide range of practices and research fields might use copies to various ends, from the history of photography to interface studies.[17] Each field contributes to the historiography and theory on the copy in different ways. Although it is not the primary intention of this article to contribute to the history or theory of copies, a few words on the profession's engagement in digitally-based reproductions are added to each of the four types outlined in the following sections.

Differentiating Digitally-Based Reproductions of Paintings

Bearing this historical backdrop in mind, linking the concepts of painting and sculpture to each other in Greimas' square seems to have the potential to clarify features in the digital field. When the complex axis is painting (S1) versus sculpture (S2), the row of the so-called contradictory terms non-painting (-S1) and non-sculpture (-S2) can be unfolded (fig. 5). As described below, different kinds of digitally-based reproductions of paintings fit into the external nodes S3, S4, S5, and S6. As touched upon above, each external node acquires features from the two nodes to which it is attached, while also differing from both of them.[18] In this way, expanding painting in the square involves judging and estimating the relations and reciprocities in the related terms. Gathering and distributing the digital and digitally-aided reproductions of paintings in the square thus result in four categories:

S3) Digital photography of painting (visible light)
S4) Analytical imaging of painting (e.g. MSI, MA-XRF, x-rays, raking light, RTI)
S5) Printing paintings in 3D
S6) Virtual 3D model of painting

It is important to emphasize that the following descriptions are non-technical and non-exhaustive. Rooted in the qualities of opposing terms in the square, the descriptions represent a bird's-eye view of the field.

Digital Photography of Painting

Which features determine where digital photography of painting might be positioned in the square? Digital photography entails a fixed viewpoint and the reduction of the three-dimensional features of the painting. Using a photograph as a means of expression increases the

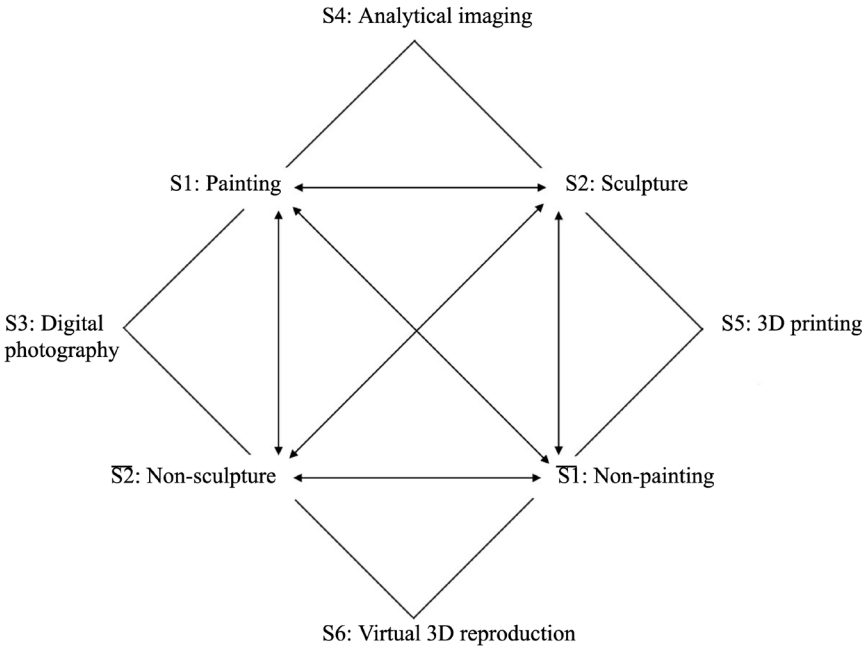

Figure 5. The painting and its digitally-based reproductions distributed in Greimas' square. Illustrated by the author.

flatness of a painting and underlines its non-sculptural being. Even high-resolution photographs that may convey an impression of the texture of the surface flatten the surface appearance. In sum, the digital photo, either printed or as an interface, delivers a copy of the painting that reduces its three-dimensionality as an artifact. At the same time, the photograph may resemble the painting well at first glance. This means that digital photography is close to both painting as a concept but also to non-sculpture since traditional photography fails to convey the corporeality of paintings. Consequently, digital photography as a type seems likely to occupy a position between painting and non-sculpture (S3).

In studies of art history, digital photography (which is taken with visible light evenly distributed on the surface) is used most frequently in the reproduction of paintings. Typically, only the front of the painting is captured and archived. Digital photography is also the most widely distributed and exchanged type of digital reproduction for paintings. The production of and access to high-quality photographs of artifacts have increased significantly in recent decades, which is a useful development for educators, researchers, and the general population alike. Professional digital photographs often make the composition of paintings clear and legible, making it easy to view details of the composition and conduct a basic visual analysis. Even so, when the actual artifact is studied in person, there may be surprises such as color variation, unexpected disparities in scale and relations, and noticeable differences in overall expression. This issue has been referred to as "the problem of the yellow milkmaid," where the circulation of color distorted, yellowish photographs of the famous painting of a milkmaid by Johannes Vermeer (1632-1675) created false expectations among the visitors of the museum.[19] Because the computer screen is an interface, the local calibration of colors adds another distorting dimension. Furthermore, the reproduced painting may be distorted because it appears as a fluorescent image on the computer screen, where its materiality—its presence as an object—is reduced dramatically in the individual display. The consequences of this reduction in the mediation process become even more tangible when producing data visualizations of thousands of recorded artifacts based on neural network analysis and clustering techniques.[20] Reduction is also evident in the high-resolution photographs available of famous paintings like *The Night Watch* (1642) by Rembrandt van Rijn (1606-1669) and *The Girl with the Pearl Earring* (c. 1665) by Vermeer. Even though the visualizations deliver detailed and particular experiences on the screen, they only provide fixed glimpses of the surfaces. Even so, and in contrast to the experience of accessing paintings in person, this fragmented viewing process may provide more information

than the human senses can obtain from experiencing the artifact itself. In this sense, the acts of reducing and expanding paintings in the digital realm may coexist. One could argue that each reduced version of a painting may contribute to an expanded experience. This perspective becomes even more pertinent in the case of analytical imaging, which is explored in the next section.

As already noted, digital photography only captures a fraction of the features that paintings convey to the human senses. In general, it is important to bear this limitation in mind when analyzing digital reproductions of paintings. The notion that photography involves interpretation is familiar in art history, but it is worth repeating when other disciplines like computer science analyze the photographic documentation of artifacts. The cogency of the computer's analysis of copies is tied to the limitations and method of recording the artifacts. These limitations might not matter in instances such as artistic reuse or learning activities in schools that utilize photo documentation of cultural heritage. However, the representational link between artifact and photo, or the lack of it, can be decisive in specific studies in art history or conservation.

Even though it is still a priority to experience paintings first-hand, art historians are often able to work with high-resolution photographs as a substitute. Conservators, on the other hand, may need further information about the status of a painting's surfaces and material components in order to inspect it properly and design a strategy for its preservation. In this profession, which is similar to the practice of medicine, paintings are examined so that diagnoses can be established and decisions made.[21] Various techniques such as X-Ray and microscopy have long been used in this examination process, and the development of new techniques in digital technology have added substantially to this repertoire over the past decade. In this practice, the number of technical or so-called analytical images of paintings steadily grows.

Analytical Imaging

In comparison to the other digital reproductions of paintings positioned in the Greimas square, analytical images are characterized by their strong representational ties to the artifacts that are being recorded. This is one reason why they are considered a legitimate source of information when interpreted by professionals. Viewing analytical images together with the painting in question informs the trained eye, and to some extent, they can also be read by the untrained eye. In this way, these images can enhance the experience and understanding of the painting and its figurations as such. With this in mind, it would make sense to place analytical imaging close to the definition of painting in the square (S4). Conveniently, one may also argue for a connection to the concept of sculpture because the images, as described above, express material components and support an understanding of a painting in three dimensions: the built-up layers, the physical structure that supports the paint layers, and other kinds of additions and supports.

When working with cultural heritage, many different professions and academic disciplines engage in the capturing, registering, and visualizing of artifacts and cultural remains in a wide sense. In studies of painting, some of the professionals involved in these procedures are technical photographers, conservators, and conservation scientists. These specialists are capable of capturing and interpreting the physical structures of artifacts, thus paving the way for a broader contextualization of these artifacts and helping to make decisions regarding preservation strategies.

A number of different images are produced in relation to the documentation of paintings. These analytical images can provide information on the compound of material components such as layers of paint, underdrawings, canvas, or wooden support. Some images are the result of photography-based techniques such as multi- and hyper-spectral imaging, where the properties of different wavelengths like infrared and ultraviolet light are exploited. Imaging techniques including X-Ray and MA-XRF scanning likewise generate visualizations of different physical aspects. This means that physical properties of paintings can be visualized and the resulting images can form the basis for further interpretation. In this way, conservators may be informed both by the physical handling of a painting and by the interpretation of its associated digital images. A painting's overall evaluation is thus underpinned by technical aids, and its interpretation may include visual, numerical, and contextual information.

Even though some analytical images are displayed at exhibitions, they are most often produced for an instrumental function in preservation and scientific procedures. Though it may be possible for a layperson to make visual links between the artifact and its analytical images and, for instance, see hidden modifications in the composition, it requires training and expertise to recognize structures and interpret these kinds of images. It is not the aim of this article to go through the different imaging techniques, but it is worth offering a few words on this category of images and how they relate to the representation of paintings.

In general, analytical images are digital, two-dimensional representations that support a virtual, three-dimensional excavation of, for instance, a painting's material layers and components. In other words, even though the painting is represented two-dimensionally on an interface,

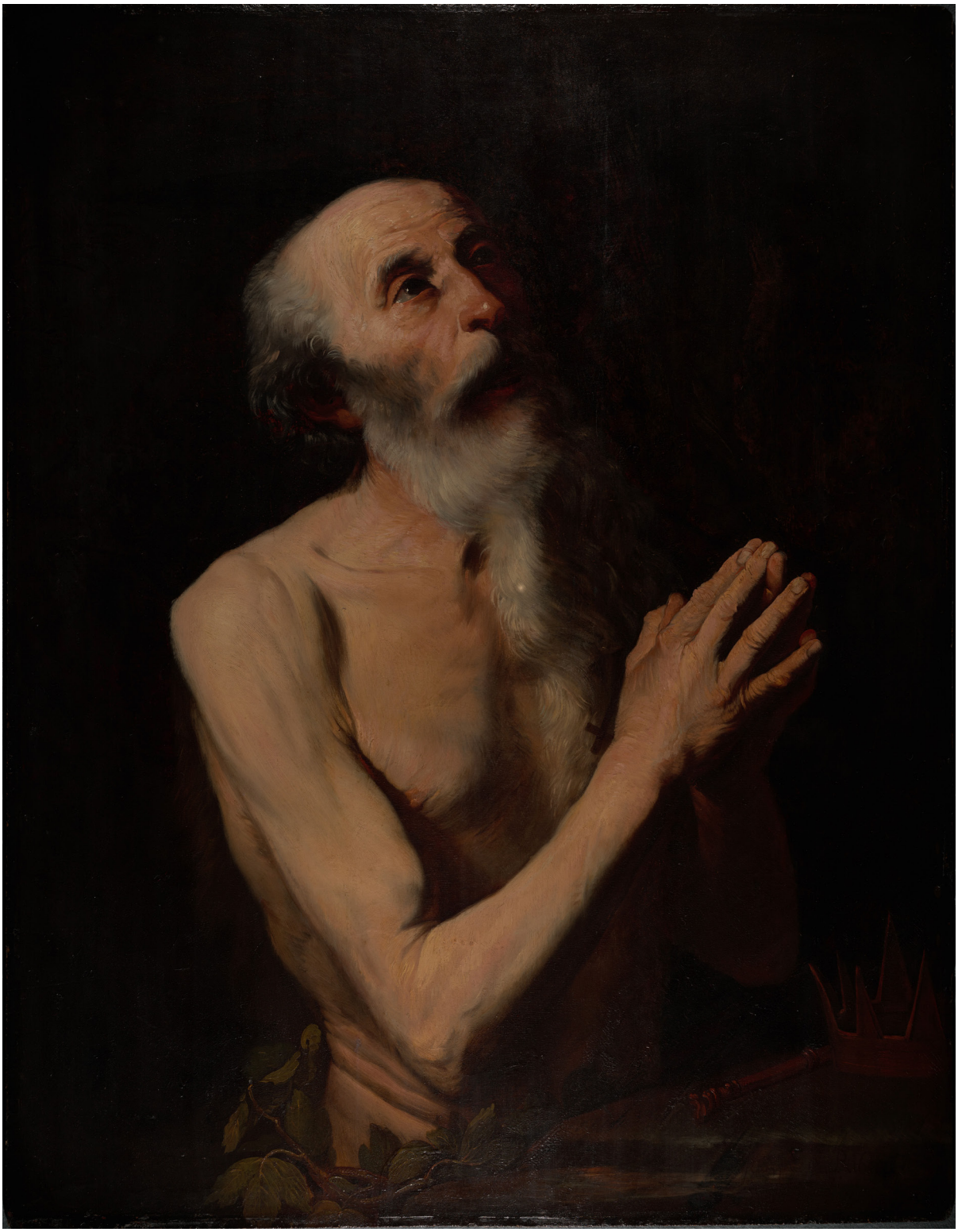

Figure 6. Artist unknown; Onuphrius the Hermit; 1637-1764; Copy after Giuseppe Ribera (1591-1652); Oil on wood; 91 x 70.5 cm; Statens Museum for Kunst. https://open.smk.dk/artwork/image/KMSsp52.

the analytical images represent and flesh out the painting as a three-dimensional object. In this way, non-destructive imaging techniques make it possible to explore the inside of the painting to a certain extent without pulling it apart or taking samples like cross-sections. In other words, the materiality of the painting is reframed for the human eye.

In a case from my research project mentioned above, I felt a profound sense of excavation when examining a painting with analytical imaging techniques. The painting Onuphrius the Hermit in the style of Giuseppe Ribera (1591-1652) is of unknown date and entered the collection of SMK in 1764.[22] It was analyzed, recorded, and examined using multiband photography (MSI), MA-XRF scanning, microscopy, and X-Ray photography (fig. 6, fig. 7 and fig. 8). The different types of visualizations allowed an underlying painting and its scenery, The Rest on Flight into Egypt, to appear. Further examination of the digital data visualizations revealed white highlights on Virgin Mary's clothing proving that the overpainted painting had been completed before it was covered up. The results of this research will be discussed in another article, but in this context, it is relevant to point out that this artifact containing two paintings became the source of a plethora of analytical images. A great amount of data was produced in the evaluation process, which became the source of visualizations and further interpretation.[23] The MA-XRF scanning in particular generated significant information about the distribution of elements in the painting's components thus providing a probability for estimating the pigments used. The scanner hits the surface with radiation, point by point, and detects elements by analyzing the emitted fluorescence radiation. Each point's dataset is then combined and mapped in visualizations of each element. In this case, the MA-XRF distribution images of the elements mercury (Hg), copper (Cu), and lead (Pb), were combined into an image that made the presence of the two paintings visible (fig. 7). Though the complex MA-XRF image is highly constructed and symbolic, it also offers insight into the painting as such. This kind of visualization exemplifies the extent to which the painting can be expanded visually in the digital realm.

Analytical imaging is interesting because the techniques and visualizations make the structures, material components, and figurations contained in the painting visible. In this way, the images offer different visual information and representation of the paintings rather than just showing what is depicted. These images are not artistic interpretations (though they can sometimes appear as such), but kinds of abstractions. The difference between a painting and its associated images also reminds us that the recording process and the computer's rendering are acts of interpretation.

Different digital tools have been developed to support the process of interpreting such images, for instance, the so-called curtain viewers, which coordinate a produced stack of images and allow them to be displayed or combined (fig. 9).[24] As a means of visualization, these tools externalize (to some extent) the process of comparing and analyzing photographs through digital image management. The tools and their continuous development become ever more important with today's growing number of images and the need for cross-disciplinary communication.

Printing Paintings in 3D

Digital photography and analytical images are typically accessed on computer interfaces if they are not developed any further. In the process of 3D printing a painting, the result is a physical object. The third external node of the square represents the combination of sculpture and non-painting (S5). The 3D print fits this node because it is the most sculptural copy of the painting in the physical sense, though it is also different from the painting in terms of production and visual appearance.[25] Unless the 3D print is painted afterwards, the object is not a painting. While the 3D print primarily emphasizes the volume of the painting, the copy only to a limited extent conveys the expressive means of the paint. It is limited to an often monochrome, processed surface with minor indications of the figurations depicted. The painting's features like colors, thin layers, and representational space are highly reduced aspects in this kind of copy. Placing 3D-printed paintings between sculpture and non-painting in the square underlines the possibility of ignoring these predominant features of painting. The copy stimulates perceiving painting as a three-dimensional object while also exposing the inherent tension between painted surface and its physical carrier that is seamlessly reproduced in the copy. The 3D print also elucidates that painting is a fragile category. From this perspective, the paint layer can easily be perceived as an asset or integral to a three-dimensional structure that equally communicates meaning, for instance a church or decorative arts objects. In this way, the concepts of painting and sculpture easily overlap and therefore they also tend to collapse in the square.

In the process of making a 3D print, the painting and its surface are measured and then modeled virtually in relief. The 3D printer converts the virtual model into a material copy in a chosen substance, for instance, a plastic. In this way, the form is interpreted and re-materialized, signaling ambiguous visual and tactile relationships to the painting it imitates. Most often, the process of converting a painting into a 3D product does not rely solely on enlarging and reproducing the actual texture of a painted surface. In many cases, a relief of the imagined space and volume of the depicted figurations is

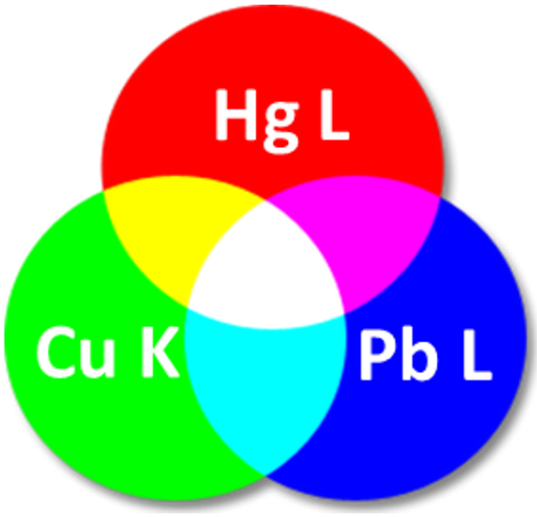

Figure 7A: Color code of distribution map. Hg: vermilion (red). Cu: Copper-based material (green). Pb: lead white (blue).

Figure 7B: Distribution map of MA-XRF-scanning of Onuphrius the Hermit (fig. 6); 2022; The painting is tilted towards the left; Image reproduced with permission of Annette Ortiz, Statens Museum for Kunst.

also imprinted on the surface. From an art historical point of view, this can be problematic in communicating and mediating a piece of art because it is based on causal, subjective choices. This element of production becomes palpable in examples such as the 3D printed version of the painting *George III in Coronation Robes* (1761) by Allan Ramsay (1713-1784).[26] In the 3D depiction of George III, this type of composition is closely tied to an established iconography. The combination of visual elements is based on well-known symbols and figurations. This premise makes it easier to convert each element into a legible relief and communicate the supposed message of the painting. However, the question is still how to qualify and improve the mediation from a professional standpoint in art history.

In general, it is evident that the borderlines between pictorial elements, foreground, and background are challenging features to reproduce in the 3D prints. The transitions between these elements often seem casual and abrupt. It would also require further development in 3D technology to express features like atmosphere or abstract figurations. The challenges with 3D prints of paintings become obvious when looking at the examples of The Mona Lisa (1503) by Leonardo da Vinci (1452 - 1519) re-expressed in three dimensions. Some of these examples show how the paintings' propertie are selected and to a great extent re-interpreted. For instance, in one version, the almost invisible garment around Mona Lisa's head is made very thick, while the landscape in the background is neglected.[27] This means that certain elements are accentuated in order to obtain the relief structure, while others are absent. What are the arguments for these formal choices that might change the sensation and understanding of the painting fundamentally?

In some museums, 3D prints of paintings have been produced to enable visually-impaired people to get a sense of the selected works of art and their illusionistic effects. One of the positive effects of printing paintings is that word-based description is bypassed so that the visitor can connect with visual arts through touch instead.[27] It is important for museums to be inclusive to visually-impaired visitors in experiencing paintings, but a critical eye towards the quality of the outcomes from an art historical point of view seems to be neglected in the celebration of technological advances. It is increasingly important to scrutinize implicit bias and decisions made in curating the features of the mediated paintings. In this case, both technology and art history frame the artifact.

The potential of 3D printing still deserves further exploration alongside the development of actual applications or uses in relation to cultural heritage research disciplines. Even the heavily promoted and famous case of replicating Rembrandt's painting technique, portrait style, and choice of composition using 3D printing and AI-based methods reveals that the purpose of doing this still seems undeveloped from an art historical perspective.[28] As Sonja Drimmer and Christopher Nygren argue, advances in computer science that the Rembrandt case might represent does not necessarily respond to any research question in art history.[29] Having said that, a recent article by Umair Malik, Liselore Tissen, and Arnold Vermeeren indicates that the intended target groups (designers, museum visitors, art historians and others) recognize the usefulness of 3D printed artifacts.[30] However, 3D printing paintings is a practice that still needs to be developed, explored, and reflected upon in order to become a proper tool for art historical research and communication.

Virtual 3D Models of Paintings

The last node in the square is attached to non-painting and non-sculpture (S6). Virtual copies of paintings fit this position in the square, which has the greatest distance from both concepts of painting and sculpture. Even though the virtual model ideally unites the paintings' visual composition with its spatial dimension, the outcomes still deliver an expression that is very different from the artifacts they depict. The virtual 3D representation of a painting is the only one out of the four kinds of representations distributed in the square that demands a contextual setting to represent it. In augmented reality, the virtual painting is in dialogue with the user's physical surroundings, whereas the virtual reality version would require some kind of virtual, spatial setting (even if it is an empty space). This adds another challenge to modeling a chosen artifact when its surroundings and influence must be included in the representation. Furthermore, both the virtual 3D models and the earlier mentioned 3D printed paintings accommodate and reinterpret the interactive aspect of experiencing the artifact.

In the race to document artifacts, there is an urgent need to demarcate subsets of features that must be captured in each copy. This is important in order to limit digitization expenses and to make each copy usable within the disciplinary requirements and technical capacities available today. It is still demanding to record and model the artifacts visually in a virtual space. Formal properties of the artifact such as texture, volume, transparency, color, and reflection each represent a challenge that very often have to be adjusted or added in post-production. As the virtual models of cultural heritage objects shared on the online platform Sketchfab show, the primary feature recorded in each artifact is volume.[31] The chosen artifact is scanned from multiple angles and the computer connects the measured distances and establishes a so-called

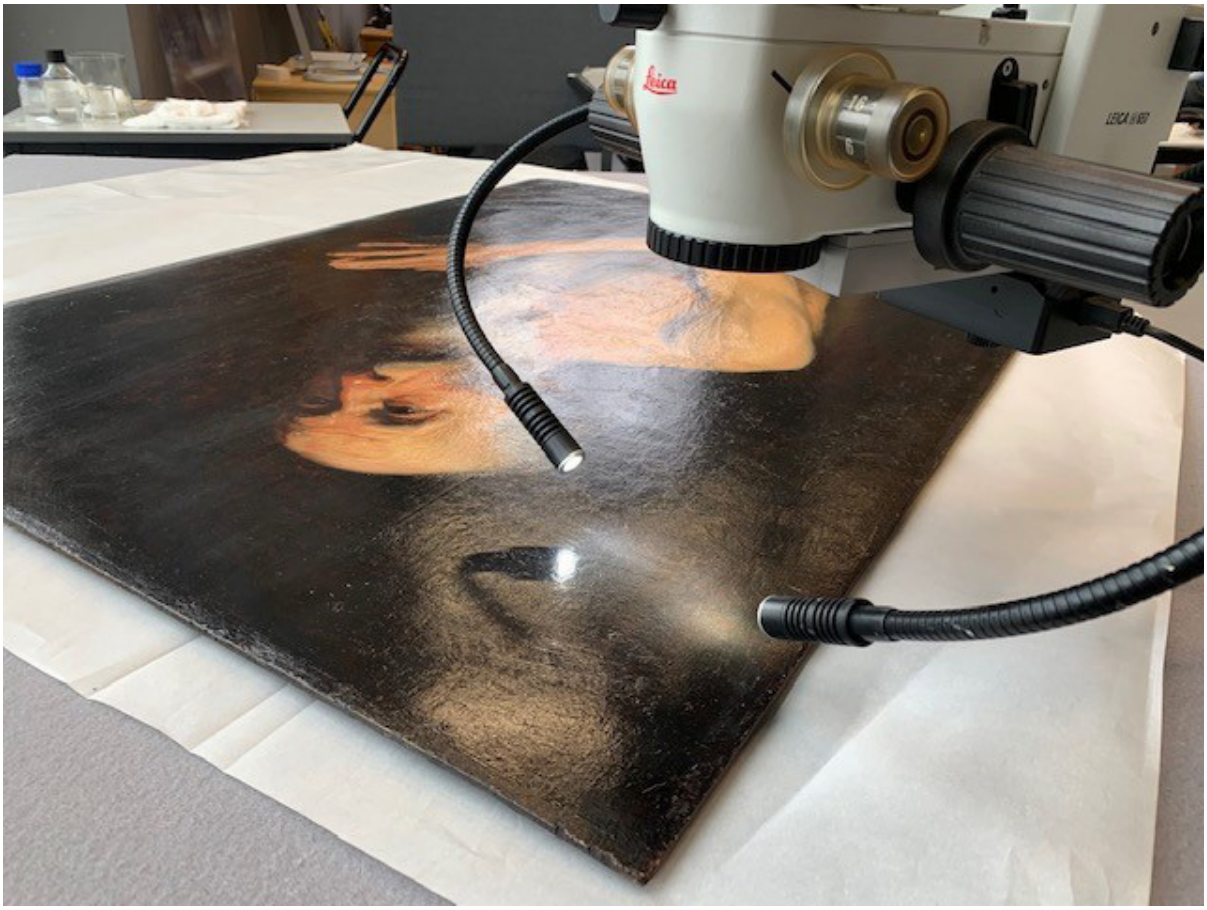

Figure 8: Examining Onuphrius the Hermit (fig. 6). Image reproduced with permission of Anne Haack Christensen, Statens Museum for Kunst.

"point cloud." The point cloud appears as hollow shapes of connected points that do not in its initial stage incorporate features such as color, texture, or a sense of solidness. Another layer of interpretation is added in the visualizing process when it comes to the chosen coding techniques and aesthetic preferences regarding how volume and surfaces are represented satisfactorily on the interface.

When the colors of an artifact are absent in its virtual model, its form is able to stand out instead, making it possible to see details, damages, or illegible writings.[32] Since paintings often present illusionistic depictions or flat compositions, their volume alone does not communicate much information about the image compared to examples of plastic arts. However, it can be useful to see the back of a painting or tilt it to study irregular surfaces, both virtually and in real life. In these interactions, features that are not visible from one angle can appear when seen from another. This can be due to visual elements hidden by reflecting light, optical play intended by the artist, damages, or other visual relations in the composition. If the virtual model has to mimic these experiences convincingly, the relation between form, texture, and color has to be developed further. Some of the imaging techniques that provide detail and texture to the virtual models are the popular technique photogrammetry and the more specialized technique reflectance transformation imaging (RTI). Especially, RTI can provide a sense of tactility and three dimensionality of a virtual artifact. The recordings of the surface of the artifact are done while illuminating it from an oblique angle, causing even subtle textural differences to appear due to the light and shadows. When moving the lightsource while recording, different patterns and shapes of the surface are rendered visible and captured.[33] Especially when this technique is used to visualize uneven surfaces of paintings and drawings, the earlier mentioned limitations of the digital photographs of artifacts in node S3 (where the surface of the artifact appears to be flat) becomes evident. The features captured with this recording technique underline the fact that experiencing paintings often involves interaction and bodily movement.

One example of a virtual, 3D version of a painting is the Girl with a Pearl Earring mentioned above where a section was reproduced virtually in three dimensions.[34] This allows for close examination by twisting, turning, and zooming in on the fragment. It has been argued that the user's experience—instead of enhanced visual realism in the renderings – must be a priority when creating virtual experiences.[35] This perspective underscores the common experience of moving around or tilting an artifact in order to sense its properties.

When it comes to paintings, the production of virtual three-dimensional representations is not a very common practice. When going through Sketchfab mentioned above, it becomes clear that this technique is not often applied to the scanning of paintings. Maybe there is not yet a very well-defined, popular need for this type of 3D reproduction when it comes to paintings that feature flat or imagined spaces in their expression. From another point of view, the technique is still expensive to use and it has a heavy carbon footprint.

As new equipment and storage opportunities become more available, scanning objects and environments in order to establish spatial virtual counterparts has become an increasingly common activity in fields concerned with cultural heritage like conservation, the history of architecture, museology, and archaeology. The use of digitization ranges from documentation, virtual reconstruction, and research investigation to education and user engagement. In museums, selected artifacts are recorded and digitized on a scale and in a variety that challenges the storage capacities of the institutions concerned. In this case, the ambition to make a so-called "virtual twin" of artifacts or even of entire settings illustrates the wide-ranging ambitions of digitization in society.

In research communication, learning material, and games, creating more accurate virtual models of paintings might have a purpose. In their study of 3D duplicates of artifacts, Malik, Tissen, and Vermeeren emphasize the difference between what is required for research purposes and for engaging an audience. Whereas precision is paramount when replicating a physical object for a scientific purpose, the quality of user experience and narrative layers is in greater demand when it comes to the use of 3D copies for museum visitors.[36] Even though these statements are reasonable, the question remains: what kind of precision is needed in each case? Narrative layers or a track of meta-communication may be reasonable features for museum users and researchers alike. In the example of the 3D model fragment of Girl with a Pearl Earring, it is important to the researcher that both the topography of the surface is correctly depicted and that contextual information and metadata on the model is attached. Information on the process of making 3D visualizations, the technique's limitations, and the critical points of production could facilitate both ends: meaning making and transparency. To the layperson, it can be more important to be able to recognize the represented figurations and navigate the model in the interface. In both contexts – research and exhibition production – it is relevant to ask about the accuracy of data visualization, why it may have flaws or undetermined areas, and which choices were made in the reproduction process.

The recent efforts to recreate and represent paintings with digital technology make it ever more important to be transparent in the process of choosing which formal properties to represent or to neglect. Archaeology is a discipline that has confronted the basic challenges of converting captured data into digital and analogue visualizations of spatial settings or artifacts, for instance, scanning fragments and making 3D reconstructions. Compared to art history, archaeology is far ahead in including digital technology in its methodologies. However, cultural heritage disciplines share common issues in this digital field. This is not the place to develop this point, but archaeologists, art historians, and conservators in particular might have an interest in cross-disciplinary discussions on how to deal with formal features and limitations of digital reproductions of cultural heritage in general. For instance, the discussion of how to deal with material loss and uncertainty in recordings and the post-production process of 3D visualizations. As already pointed out, digital reproductions fix and mediate artifacts' appearances and measurements in order to make it possible for the computer to work with the material. This fixation is necessary and convenient. However, it may also make the conservator, archaeologist, or art historian feel uneasy when visualizations and analyses are done and conclusions are drawn without reservations about digital images and the artifacts they depict.

The Visual Culture of Painting in the Digital Sphere

The four categories in the Greimas square (S3-S6) introduced above illustrate different challenges in representing paintings digitally: Which features of the painting should be privileged or neglected in each representation? How can or should these features be interpreted and translated in the digital realm? Even though the types of representation are very different, the square unites them as a visual culture of painting in the digital realm. This visual culture steadily expands and enhances

the presence of paintings and artifacts online. At the same time, mapping digital reproductions in the square also highlights the diversity of reproductions that often exist in separate domains.

Still, these digital images originate from the painting they represent. Each professional field that utilizes these images requires precision and degrees of transparency in the production process. This makes it possible to employ images in research as documentation, in visualizations for communication, and as empirical material for analysis.[37] As described above, the representational qualities are very different. Analytical imaging takes the representational connection to the extreme, while 3D printing exposes the subjective interpretation inherent in the process of making. In other uses, the representational link between a painting and its reproductions is of lesser or no importance, for instance, when the images are used as training sets for algorithms or as material for artistic exploration. These activities are not considered in this article.

The concept of painting is taken as a point of departure in this mapping of digitally-based copies, but many other artifacts and their reproductions could also inhabit the square and display similar issues. Since many research fields use digital images as part of their research, it is increasingly important to address tacit knowledge and gray areas that pervade these practices with digital images, for instance in medicine, conservation, computer science, and archaeology.

Thickets of Representation

The following section outlines a concept of "thickets," which can describe how the visual culture of painting initiates and fosters complex processes of understanding digital images in relation to the painting they depict. The concept itself derives from biology, but my inspiration for employing thickets is the examination process of conservators. Typically, conservators have skills based on visual training, handling complex artifacts, and combining bits and pieces of tactile, visual, and text-based information.[38] These skills are also needed when working with digital reproductions of artifacts. Utilizing digital images in this field requires imagination, an acceptance of ambivalence, and a high attention to scientific standards. From a visual digital humanities perspective, the conservator's method of dealing with a cluster of information may be a source of inspiration for the field in general.[39] Though this is still a subject to explore, the concept of thickets can provide a point of departure for discussing how we experience digital images that represent an artifact.

Phenomena studied in natural science (a virus, for instance) cannot always be captured or rendered adequately in a single image. To gain some visual understanding of a non-visual phenomenon, scientists can reproduce it through a range of images that do not privilege any viewpoint. For instance, when describing species and establishing a so-called "robust knowledge," the biologist William Wimsatt refers to "causal thickets" to describe the cluster of different images that visualize a single object of interest.[40] The art historian James Elkins adapts this concept and refers to it as "thickets of representation," suggesting that thickets can be recognized in relation to a wider understanding of visual processing in different fields: "…the fascinating idea that some fields see the visual world as a 'thicket' of structurally incompatible information could be extended to other fields, and contrasted against the case in fine art, where the single image is considered sufficient and even ideal.[41] Since a painting is visually accessible to our senses, it does not demand visualizations to obtain an appearance. In addition, experiencing the painting itself is, as mentioned above, highly regarded. From another perspective, the painting as a material object is relative and in constant change. A painting's expressive means might change significantly over time and when it is placed in different settings. So, when is a single moment of experiencing a painting – either in-person or virtually – sufficient?

The various digitally-based reproductions discussed in this article make it clear that the human senses may be incapable of capturing the variety of complex images that paintings afford as material objects (whether or not they were intended by the maker). Recognizing digitally-based reproductions as thickets thus highlights the extended experience of paintings these images provide. In this perspective, equal attention is given to the possible depiction, perceptual effects, and material presence, which suspends the old hierarchy between matter and representation. This also gives equal status to the different kinds of interpretations that can be done in relation to the painting and its digital representations. All of these methods provide analytical tools and insight into the studied artifact, and the challenge lies within navigating and combining the results and thoughts.

Conclusion

In a book chapter from 2016, Lauren F. Klein and Matthew K. Gold refer to Rosalind Krauss' efforts to tease out contemporary artistic trends entangled with the concept of sculpture.[42] Klein and Gold point out the need to make similar distinctions in the field of the digital humanities. In this article, I distinguish between groups of computer-aided copies of paintings and argue that the reproductions can be seen in their entirety as a visual culture of painting.

Especially in the case of virtual 3D representations of paintings, it is clear that this method still needs thinking and technical development to become more useful and

widespread. Digital photography is a much-developed technique, and high-resolution images are used in many disciplines. Even so, as previously noted, the images have limitations because they suppress the recorded painting's three-dimensionality. These considerations may not contribute to new conclusions about actual artifacts or their digital counterparts, but this article's typology of digitally-based copies of paintings may lead to an understanding of the relationships, limitations, and possibilities that these images provide.

As the distribution in Greimas' square reveals, there is a prevalent sculptural dimension in paintings as objects: the layers, surfaces, frames, setting, etc. These features either re-appear or are neglected in digitally-based representations. Though the square keeps the definitions of painting and sculpture apart, the digital representations distributed in the nodes testify to how the dichotomy collapses when paintings are digitally-mediated. In other words, paintings also have a sculptural being, and the digitally-produced copies highlight this fact even though each digital copy that embraces three-dimensionality has trouble presenting imagined spaces and figurations.

Each discipline that produces or works with digitally-based reproductions of artifacts has its own agenda and practices. A disciplinary purpose might be to gain insight into an artifact with analytical imaging, to communicate research results, or to document conditions. These specialized working processes that employ digital images are often well-defined, but the associated practices rarely include systematic attempts to consider the resulting images and their use across disciplines.[43] In this sense, this article's application of the square brings the discussion back to basic considerations of formal features of the digitally-based copies.

When mapping digitally-based copies of paintings in the square, a fundamental insight re-emerges: approaching the artifact itself only partly communicates its material properties. From the perspective of reception aesthetics and phenomenology rooted in Maurice Merleau-Ponty's influential writings, the experience of the painting is shaped by its material conditions and the setting, but also by the person interacting with it. The user's approach to a painting is thus relative and multiplied by its digital copies, renegotiating the interaction and perception. A significant point is that a painting's potential inaccessibility and relative affordances are amplified, interpreted, and displayed when it enters the digital realm. In the process of mediation, a painting can splinter into fractions of images, communicating different aspects that may not be visually compatible or that may be difficult to comprehend as a whole. For this reason, employing the concept of thickets helps to articulate the challenge of comprehending and navigating this growing visual culture. The tension between physical artifacts and the ways in which they can (and maybe should) inhabit an imagined, virtual space continuously provides space for rich analysis.

NOTES

1 I am leading this project, which is hosted by Aarhus University and The National Gallery of Denmark (SMK) (2019-2022). The project is funded by the Independent Research Fund Denmark (DFF) and the New Carlsberg Foundation. Thanks to the SMK's conservation and science department for their generosity and hospitality. Thanks to Aurora Hoel for discussions and for recommending a closer look at Greimas' writings. Thanks to Henrik Kragh Sørensen for discussions on the Klein Group.

2 To mention a few: Mark Titmarsh, *Expanded Painting: On the Ontological Aesthetics and the Essence of Colour* (London/New York: Bloomsbury, 2019 [2017]); Ulrika Levén et al., *Måleri – Det Utvidgade Fältet / Painting – The Extended Field* (Malmö: Rooseum, 1996); Anne Ring Petersen et al., *Contemporary Painting in Context* (Copenhagen: Museum Tusculanum Press, 2013 [2010]); Isabella Graw, *The Love of Painting: The Genealogy of a Success Medium* (Berlin: Sternberg Press, 2018).

3 Rosalind Krauss, "Sculpture in the Expanded Field," *October* Volume 8 (Spring 1979): 30-44. Reprinted in: Rosalind Krauss, *The Originality of the Avant-Garde and Other Modernist Myths* (USA: The MIT Press, 1997 [1985]).

4 Lise Skytte Jakobsen, *Metaskulptur: Skulpturbegrebet i bevægelse* (Copenhagen: forlaget politisk revy, 2019), 10.

5 Krauss, "Sculpture in the Expanded Field," 37-38.

6 Krauss also illustrates her version of the semiotic square ("structuralism's graph," p. 21) on page 22 in Rosalind Krauss, *The Optical Unconscious* (Cambridge, Massachusetts, and London: The MIT Press, 1996 [1993]). In this book, she also represents Greimas' square on pages 189-192. Krauss does not comment on the difference between Greimas' square and her version. Krauss may have chosen the configuration to fit her purpose, as her selected types of artworks, marked sites, and axiomatic structures cannot fit Greimas' composition of the square. David Carrier states that Krauss' square is rooted in the square of oppositions: David Carrier, *Rosalind Krauss and American Philosophical Art Criticism: From Formalism to Beyond Postmodernism* (USA: Praeger Publishers, 2002), 40-42.

7 Algirdeas Julien Greimas and François Rastier, "The Interaction of Semiotic Constraints," *Yale French Studies*, Issue no. 41 (1968): 86-105. For the description of the implications, see p. 90.

8 Greimas and Rastier, "The Interaction of Semiotic Constraints," 1968, 86-105.

9 Fredric Jameson, *The Political Unconscious: Narrative as a Socially Symbolic Act* (Ithaca/New York: Cornell University Press, 1981).

10 For a description of how to apply the square in four steps, see Louis Herbért and Julie Tabler, "The veridictory square," in *An Introduction to Applied Semiotics: Tools for Text and Image Analysis*, ed. Louis Herbért (USA: Taylor & Francis, 2020), chapter 4, 53-62.

11 Greimas and Rastier, "The Interaction of Semiotic Constraints," 1968, 90.

12 I use the term 'square' even though many people have substituted it with 'rectangle' e.g. Jameson, *The Political Unconscious*, 1981, 46-48.

13 Krauss 1979, p. 43. Krauss only touches upon the postmodernist painting, though.

14 Laura Estill, Diane K. Jakacki, and Michael Ullyot (eds.), *Early Modern Studies after the Digital Turn* (Toronto: Iter Press, 2016); Christopher Nygren, "A Stone Through the Window of Art History: Paintings on Stone and the Legacy of Pictorial Illusionism," in *Steinformen. Materialität, Qualität, Imitation*, eds. Isabella Augart, Maurice Saß, and Iris Wenderholm (eds.) 2019 (Berlin: de Gruyter), 75-96.

15 Joris van Gastel, Yannis Hadjinicolaou and Markus Rath (eds.), *Paragone als Mitstreit* (Berlin: Akademie Verlag, 2014); Rudolf Preimesberger, *Paragons and Paragone: Van Eyck, Raphael, Michelangelo, Caravaggio, and Bernini* (Cambridge: Cambridge University Press, 2011); Ulrika Levén et al. 1996, p. 16.

16 Fiona Cameron, "Beyond the Cult of the Replicant: Museums and Historical Digital Objects – Traditional Concerns, New Discourses," *Theorizing Digital Cultural Heritage: A Critical Discourse*, eds. Fiona Cameron and Sarah Kenderdine, (Cambridge, MA: MIT Press Scholarship, 2007); Stephan Schwan and Silke Dutz, "How do Visitors Perceive the Role of Authentic Objects in Museums?" *Curator - The Museum Journal*, Vol. 63, no. 2, 2020, 217-237; Emma Stanford, "A Field Guide to Digital Surrogates Evaluating and Contextualizing a Rapidly Changing Resource," in *The Routledge Handbook of Museums, Media and Communication*, eds. Kirsten Drotner et al. (London/ New York: Routledge 2019), 203-214; Sarah Kenderdine and Andrew Yip, "The proliferation of aura. Facsimiles, authenticity and digital objects," in *The Routledge Handbook of Museums, Media and Communication*, eds. Kirsten Drotner et al. (London/ New York: Routledge 2019), 274-289.

17 Just to name a few recent examples of going into the history of photography: Kerr Houston, *The Place of the Viewer: The Embodied Beholder in the History of Art*, 1764-1968, (Leiden/ Boston, Brill, 2019); Christopher Lakey, "'To See Clearly': The Place of Relief in Medieval Visual Culture," in *Optics, Ethics, and the Transformations of Art in the Thirteenth and Fourteenth Centuries*, eds. Herbert Kessler et al. (Toronto: PIMS, Pontifical Institute of Mediaeval Studies 2018), 119-138.

18 I see this mode of establishing the external nodes or meta terms as among the different ways scholars apply the square to specific material. In this way, the meta terms stay as close as possible to the primary axes of the square.

19 Harry Verwayen, Martijn Arnoldus, and Peter B. Kaufman, "The Problem of the Yellow Milkmaid: A Business Model Perspective on Open Metadata," White Paper no. 2, 14 November 2014, https://pro.europeana.eu/post/the-problem-of-the-yellow-milkmaid (Accessed 21-10-2021). See also: *The Milkmaid*, Johannes Vermeer, c. 1660, oil on canvas, h 45.5 cm × w 41 cm https://www.rijksmuseum.nl/en/collection/SK-A-2344.

20 In this sense, the digital photograph of the painting's front captured under visible light conditions illustrates the concept I describe elsewhere as a 'reduced artifact.' This concept simply expresses the well-known fact that every digital image of the artifact only mediates and represents a subset of its features. Lisbet Tarp and Ross Deans Kristensen-McLachlan, "The reduced artifact: A case study in data visualization and digital art history," *Perspective*, 2021. https://perspectivejournal.dk/en/reduced-artefact-case-study-data-visualisation-and-digital-art-history

21 See Cecil Krarup Andersen, Beate Knuth Federspiel, and Pia Clemmesen, "Bridging Conservation Practice and Science: A Study on Encapsulations Theory and Knowledge Transfer in the Education of Conservators," *MoK – meddelelser om konservering, The Nordic Association of Conservators*, no. 1 (December 2018): 5-11.

22 See: https://open.smk.dk/artwork/image/KMSsp52.

23 Two articles and a book chapter are under production with the authors Lisbet Tarp, Anne Haack Christensen, Annette Ortiz, Gianluca Pastorelli, and Loa Ludvigsen.

24 Curtain viewers are becoming common. Lisbet Tarp, "A New View: Creating Tools to Access, Conserve, and Understand Visual Cultural Heritage," *Passepartout – skrifter for kunsthistorie*, Vol. 41 (2022): 213-227. See: https://jpadfield.github.io/simple-site/curtain-viewer.html#0

25 Naturally, the 3D print may be painted over, for instance in accordance with the imitated painting. As a composite of painting and 3D print, it might just return to the category 'painting' or else it could be the starting point for composing a new square.

26 *George III in coronation robes* painted by Allan Ramsay (1713-1784), https://www.agsa.sa.gov.au/collection-publications/collection/works/king-george-iii-in-coronation-robes/24192/ (Accessed 15-8-2022). The 3D version is made by 3DPhotoWorks and exhibited at Museum of the American Revolution: https://3dphotoworks.com/installations/museum-of-the-american-revolution/ (Accessed 15-8-2022).

27 See the stories on the website of 3DPhotoWorks: https://3dphotoworks.com (Accessed 01-08-2022), or see the article "3D printing is helping blind people 'see' Mona Lisa's smile for the very first time" by Francesca Kentish, Metro, Friday 20th of November 2015.

28 See the project "The Next Rembrandt," www.nextrembrandt.com (Accessed 07-10-2021).

29 Christopher Nygren and Sonja Drimmer, "Art History and AI: Ten Axioms," *International Journal for Digital Art History*, no. 9, April (2023): 5.02-5.13. DOI: https://doi.org/10.11588/dah.2023.9.90400

30 Umair Malik, Liselore Tissen, and Arnold Vermeeren, "3D Reproductions of Cultural Heritage Artefacts: Evaluation of Significance and Experience," *Studies in Digital Heritage*, Vol. 5, Issue no. 1 (2021): 1-29. https://doi.org/10.14434/sdh.v5i1.32323

31 Repository at Sketchfab: https://sketchfab.com/store/3d-models/cultural-heritage-history?ref=header (Accessed 24-04-2023).

32 The focus on surface structure rather than color is central to the RTI scanning technique. An example of scanning illegible surfaces: https://blogs.illinois.edu/view/7923/804792 (Accessed 24-04-2023).

33 Link to videos with examples of performing reflectance transformation imaging (RTI) where the artifact is recorded when illuminated from different angles: https://youtu.be/P8oRt_gU0pM and https://youtu.be/zddxcSayxcg (Accessed 20-4-2023).

34 In the project The Girl in the Spotlight, partial virtual 3D reconstructions were made of the surface. Project website: https://hirox-europe.com/PEARL/3D/ (Accessed 13-02-2023).

35 Bernadette Flynn, "The Morphology of Space in Virtual Heritage," *Theorizing Digital Cultural Heritage: A Critical Discourse*, eds. Fiona Cameron and Sarah Kenderdine (eds.) (Cambridge MA: MIT Press Scholarship Online, 2007), 349-368.

36 Malik, Tissen, and Vermeeren, "3D Reproductions of Cultural Heritage Artefacts," 2021.

37 There are, of course, some applications that do not depend on a representational relation to the recorded artwork. For instance, photographs of artifacts may be used as training datasets to strengthen the robustness of algorithms.

38 Mark Leonard, ed. *Personal Viewpoints: Thoughts about Paintings Conservation*, (Los Angeles: The Getty Conservation Institute, 2003), 4 and 12.

39 For the term visual digital humanities, see Sander Münster and Melissa Terras, "The Visual Side of Digital Humanities: A Survey on Topics, Researchers, and Epistemic Cultures," *Digital Scholarship in the Humanities* 35, no. 2 (2019): 366-389.

40 William Wimsatt, "The Ontology of Complex Systems: Levels of Organization, Perspectives, and Causal Thickets," *Canadian Journal of Philosophy* 24 (1994): 207-274.

41 James Elkins, "Visual Practices Across the University," in *Beyond Mimesis and Convention: Representation in Art and Science*, eds. Roman Frigg and Matthew Hunter (Dordrecht: Springer, 2010), 190. For the concept of "thickets," see also, Elkins and Erna Fiorentini, *Visual Worlds: Looking, Images, Disciplines* (New York: Oxford University Press, 2021).

42 Lauren Klein and Matthew Gold, "Digital Humanities: The Expanded Field," in *Debates in the Digital Humanities*, eds. Lauren Klein and Matthew Gold (Minneapolis and London: University of Minnesota Press, 2016), ix-xvi.

43 The instrumental aspect of image use and production has been described by Horst Bredekamp, Harun Farocki, Aurora Hoel, Lorraine Daston and Peter Galison among others.

BIBLIOGRAPHY

Andersen, Cecil Krarup, Beate Knuth Federspiel, and Pia Clemmesen. "Bridging Conservation Practice and Science: A Study on Encapsulations Theory and Knowledge Transfer in the Education of Conservators," *MoK – meddelelser om konservering*, The Nordic Association of Conservators, no. 1 (December 2018): 5-11.

Cameron, Fiona. "Beyond the Cult of the Replicant: Museums and Historical Digital Objects – Traditional Concerns, New Discourses." In *Theorizing Digital Cultural Heritage: A Critical Discourse,* edited by Fiona Cameron and Sarah Kenderdine, 49-75. Cambridge, MA: MIT Press Scholarship, 2007.

Carrier, David. *Rosalind Krauss and American Philosophical Art Criticism: From Formalism to Beyond Postmodernism*. USA: Praeger Publishers, 2002.

Drimmer, Sonja and Christopher Nygren. "Art History and AI: Ten Axioms." In *International Journal for Digital Art History*, no. 9, April (2023): 5.02-5.13. DOI: https://doi.org/10.11588/dah.2023.9.90400

Elkins, James and Erna Fiorentini. *Visual Worlds: Looking, Images, Disciplines.* New York: Oxford University Press, 2021.

Elkins, James. "Visual Practices Across the University." In *Beyond Mimesis and Convention: Representation in Art and Science*, edited by Roman Frigg and Matthew Hunter, 169-192. Dordrecht: Springer, 2010.

Flynn, Bernadette. "The Morphology of Space in Virtual Heritage." In *Theorizing Digital Cultural Heritage: A Critical Discourse,* edited by Fiona Cameron and Sarah Kenderdine, 349-368. Cambridge MA: MIT Press, 2007.

Gastel, Joris van, Yannis Hadjinicolaou, and Markus Rath, eds. *Paragone als Mitstreit.* Berlin: Akademie Verlag, 2014.

Graw, Isabella. *The Love of Painting: The Genealogy of a Success Medium.* Berlin: Sternberg Press, 2018.

Greimas, Algirdeas Julien and François Rastier. 'The Interaction of Semiotic Constraints.' *Yale French Studies*, Issue no. 41 (1968): 86-105.

Herbért, Louis and Julie Tabler. "The Veridictory Square." In *An Introduction to Applied Semiotics: Tools for Text and Image Analysis*, edited by Louis Herbért, 53-60. USA: Taylor & Francis, 2020.

Houston, Kerr. *The Place of the Viewer: The Embodied Beholder in the History of Art*, 1764-1968. Leiden/Boston, Brill, 2019.

Jakobsen, Lise Skytte. *Metaskulptur: Skulpturbegrebet i bevægelse*. Copenhagen: Rævens Sorte Bibliotek, forlaget politisk revy, 2019.

Jameson, Fredric. *The Political Unconscious: Narrative as a Socially Symbolic Act*. Ithaca/New York: Cornell University Press, 1981.

Kenderdine, Sarah and Andrew Yip. "The Proliferation of Aura. Facsimiles, Authenticity and Digital Objects." In *The Routledge Handbook of Museums, Media and Communication*, edited by Kirsten Drotner et al., 274-289. London/ New York: Routledge 2019.

Klein, Lauren and Matthew Gold. "Digital Humanities: The Expanded Field." In *Debates in the Digital Humanities*, edited by Lauren Klein and Matthew Gold, ix-xvi. Minneapolis and London: University of Minnesota Press, 2016.

Krauss, Rosalind. 'Sculpture in the expanded field.' *October* 8 (Spring 1979): 30-44.

Krauss, Rosalind. *The Originality of the Avant-Garde and Other Modernist Myths.* 11th edition. USA: The MIT Press, 1997 [1985].

Krauss, Rosalind. *The Optical Unconscious*. Fourth printing. Cambridge, Massachusetts, and London: The MIT Press, 1996 [1993].

Lakey, Christopher. "'To See Clearly': The Place of Relief in Medieval Visual Culture." In *Optics, Ethics, and the Transformations of Art in the Thirteenth and Fourteenth Centuries*, edited by Herbert Kessler, Richard Newhauser, and Arthur Russell, 119-138. Toronto: PIMS, Pontifical Institute of Mediaeval Studies, 2018.

Leonard, Mark, ed. *Personal Viewpoints: Thoughts about Paintings Conservation*. Los Angeles: The Getty Conservation Institute, 2003.

Levén, Ulrika, Evalena Lidman, David Neuman, and Bo Nilsson. *Måleri – det utvidgade fältet / Painting – the extended field.* Malmö: Rooseum, 1996.

Malik, Umair, Liselore Tissen, and Arnold Vermeeren. "3D Reproductions of Cultural Heritage Artefacts: Evaluation of significance and experience." *Studies in Digital Heritage*, Vol. 5, Issue no. 1 (2021): 1-29. https://doi.org/10.14434/sdh.v5i1.32323

Münster, Sander and Melissa Terras. "The visual side of digital humanities: a survey on topics, researchers, and epistemic cultures." *Digital Scholarship in the Humanities* 35, no. 2 (2019): 366-389.

Nygren, Christopher. "A Stone Through the Window of Art History: Paintings on Stone and the Legacy of Pictorial Illusionism." In *Steinformen. Materialität, Qualität, Imitation*, edited by Isabella Augart, Maurice Saß, and Iris Wenderholm, 75-96. Berlin: De Gruyter, 2019. https://doi.org/10.1515/9783110583618

Petersen, Anne Ring et al. *Contemporary Painting in Context*. Copenhagen: Museum Tusculanum Press, 2013 [2010].

Preimesberger, Rudolf. *Paragons and Paragone: Van Eyck, Raphael, Michelangelo, Caravaggio, and Bernini.* Cambridge: Cambridge University Press, 2011.

Schwan, Stephan and Silke Dutz. "How do Visitors Perceive the Role of Authentic Objects in Museums?" *Curator - The Museum Journal*, Vol. 63, no. 2 (2020): 217-237.

Stanford, Emma. "A Field Guide to Digital Surrogates: Evaluating and Contextualizing a Rapidly Changing Resource." In *The Routledge Handbook of Museums, Media and Communication*, edited by Kirsten Drotner et al., 203-214. London/ New York: Routledge, 2019.

Titmarsh, Mark. *Expanded Painting: On the Ontological Aesthetics and the Essence of Colour*. London/New York: Bloomsbury, 2019 [2017].

Verwayen, Harry, Martijn Arnoldus, and Peter Kaufman. "The Problem of the Yellow Milkmaid: A Business Model Perspective on Open Metadata." White Paper no. 2, 14 (November 2014), https://pro.europeana.eu/post/the-problem-of-the-yellow-milkmaid (Accessed 21 October 2021).

Wimsatt, William. "The Ontology of Complex Systems: Levels of Organization, Perspectives, and Causal Thickets." *Canadian Journal of Philosophy* 24 (1994): 207-274.

LISBET TARP is associate professor in the department of Art History at Aarhus University, Denmark. Her research is mainly concerned with early modern studies of Western art and culture. She was leader of the research group project Digital Art History: Rediscovering the Painting (2019-2022), which was conducted in collaboration with the National Gallery of Denmark (SMK). The project was funded by the New Carlsberg Foundation and the Independent Research Fund Denmark.

Correspondence email address: tarp@cc.au.dk