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Better Sensors, Better Forgers: An Adversarial Loop

ABSTRACT

This essay zooms into the topic of art forgeries and how the refinement of authentication methods and the dissemination of the resulting expert knowledge has led to detectives and forgers alike being better prepared. Following a brief navigation into the mechanics of art forensics, it discusses several relevant case studies that display the importance of authority delegation in solving the puzzle of authentication.

In art attribution, a consensus needs to be reached between the main forgery detection "sensors": the eyes of art historian for stylistic diagnostic; the eyes of hardware analytical and optical devices that gather scientific evidence; the eyes of the scientific experts to interpret the latter properly. Particular focus is given to the correlated effects activated by the increasing popularity of digitization of cultural heritage (CH) objects. Digital repositories of cultural heritage scientific data have themselves become a subject for forgery and contamination. This introduces the need to dive into a new typology of sensors: forensic software, that can identify the alteration of scientific images. Nonetheless, software may also be employed by forgers to maliciously modify digital data in order to influence a certain diagnostic. This essay frames all the above-mentioned aspects in a cyclic adversarial process, where the progress of sensors determines that of forgers and vice versa. Finally, ethical and legal considerations are explored with respect to the prevention of art forgeries and the reciprocal influence between researchers and forgers.

KEYWORDS. Sensors, Adversarial Framework, Cultural Heritage, Digitization, Artificial Intelligence.

I. INTRODUCTION

Given the high numbers and turnover that are at stake in the art market, authentication studies and forgery detection have sparked the interest of not only the research and scholarship community (Craddock 2009, Scott 2007, Khan *et alii* 2018), but that of the general public as well. So much so, that the British Broadcasting Corporation sponsored a documentary/investigation series called "Fake or Fortune?", where a journalist and art dealer investigate cases of authentication of works of art (mostly paintings) by resorting to multidisciplinary analyses, so as to track the provenance, as well as the stylistic similarities and scientific coherence (BBC 2019). Furthermore, two feature movies are conveying different shades of forgeries: Giuseppe Tornatore's "The Best Offer" (2013) and Philip Martin's "The Forger" (2014). Even though the movies are fictional stories, the underlying morals include a big share of reality. The latter is an art heist case whose target is Monet's "Woman with parasol" displayed during a temporary exhibition. The original painting is stolen from the museum and replaced with a copy, thus the heist goes unnoticed. The forger portrayed in the film is an art-talented thief that has knowledge not only about art history and techniques, but also about the scientific methods of painting investigation: he is aware of the period substrate investigation, and so he buys a canvas of a lesser-known artist painted in the same year as the original "Woman with Parasol". He then orders historically accurate pigments that Monet was known to have used and assumes that the scientists will check the anachronism of the materials. Thus, the forger showcases himself as an informed and knowledgeable concealer who anticipates the scientific investigation of his fraud. In parallel, "The Best Offer" spotlights a famous art expert who works as art auctioneer and abuses his incontestable authority in the field to misattribute originals and belittle their value so that they can be sold for an affordable price to a friend auctioneer, after which he himself can buy them for his personal collection. Such an original painting that gets miscatalogued for a less valuable painting is called "a sleeper" (BBC 2019) and exists as a reality in the art market. Moreover, the plot of "The Best Offer" movie reveals how, in the end, even an impassible art expert can be deceived if he lets his judgement be fogged by emotional interferences.

All the above-mentioned examples introduce several of the key arguments in this essay, as follows.

The dissemination of knowledge on authentication methods to the general public runs the risk of this knowledge being imparted to forgers, who can then use it to perfect their concealing techniques. Moreover, while keeping the authentication judgements on the objective side, scientific investigation is not a stand-alone entity in authentication studies. It has to be supported by provenance proofs, an "unbroken chain of custody" and by the confirmations of art historian regarding the stylistic and semantic integrity that ascertains the artist's expression. In addition, all this evidence needs to be supported by cooperative ethical and legal measurements in order to avoid the contamination of the art market with forgeries. These aspects will be discussed in the first part of the essay (section 2).

Moreover, the digital era is bringing new challenges for cultural heritage and adds new layers of complexity to modern authentication studies. More than a medium, digital has become a form of creative expression and a legacy in its own right, whether it concerns a digitally created object

or a digitized rendering of an already existing cultural heritage item. This is an aspect that has not escaped the attention of policy-makers. As a matter of fact, the European Framework for Action on Cultural Heritage (European Commission 2019) puts forward a definition of its own to the digital cultural heritage: "cultural heritage consists of the resources inherited from the past in all forms and aspects - tangible, intangible and digital (born digital and digitized), including monuments, sites, landscapes, skills, practices, knowledge and expressions of human creativity, as well as collections conserved and managed by public and private bodies such as museum, libraries and archives".

The second part of this essay (section 3) will tackle the implications of digitization in matters of authentication. In particular, it will showcase how repositories of digitized cultural heritage can be altered with software tools in order to support attribution instances. At the same time, it will argue to what extent forensic software can be used to recover the digital fingerprint of digital scientific data. Furthermore, this essay introduces the term of "reverse-engineering digitization" for referring to cases where digitized and born-digital heritage can be used as sources of inspiration for real, tangible replicas, where copyright regulations are rather fuzzy. Since new artificial intelligence algorithms have been trained to generate realistic-looking paintings, this "reverse-engineering digitization" might represent a potential new tool for forgers. Nonetheless, software tools can serve both forgers and detectives alike in art authentication studies.

Fig. 1 depicts a graphical representation of the concepts analyzed in this article. Sensors and forgers are placed in an adversarial learning loop whereby, competing with each other, they push for each other's progress. This progress is influenced by media used for producing and disseminating knowledge. Digital technologies are nowadays essential in this process.

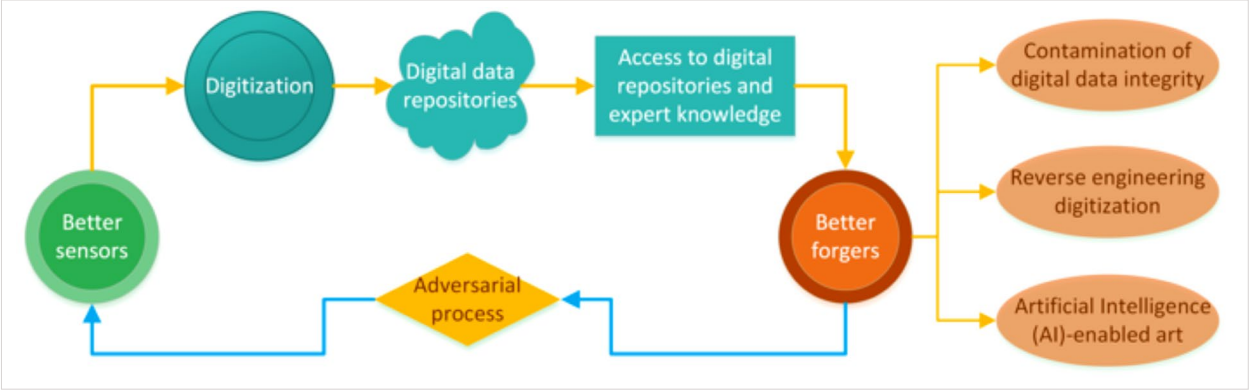

Fig. 1. This essay discusses the adversarial process between sensors and forgers, that mutually improve each other in the context of art authentication studies. Particular attention is given to the implications of digital technologies for producing and presenting knowledge, which act as an intermediary between the two ends of the adversarial framework.

II. BETTER SENSORS, BETTER FORGERS

This section is a brief overview of the reciprocal progress of sensors and forgers, highlighting key case studies.

2.1 Better Sensors

In the monograph entitled "Scientific Investigation of Copies, Fakes and Forgeries" (Craddock 2009), Craddock, a conservation scientist at British Museum, recommends three steps towards the study of authenticity: the observation and visual examination, material analysis, and physical age determination. Similarly, Brainerd (Brainerd *et alii* 2007) reiterates these methods as: provenance, dating and connoisseurship (Overgaard and Loiselle 2017).

The visual inspection can be magnified by microscopes and enhanced by using light sources with different spectral power distributions (infrared, ultraviolet) or placed at different illumination angles (raking or grazing angles) (Craddock 2009). The various modulations in light frequency or angularity can unveil peculiar elements in a work of art (Ciortan *et alii* 2018), such as repairs super-positions of materials or patches of foreign materials, or they can enhance the visibility and legibility of inscriptions or signatures in an otherwise poor display condition (Johnson *et alii* 2014). Because certain pigments, binders and varnishes fluoresce under ultraviolet (UV) light, restorations and inconsistencies can be detected by having different intensities in the UV fluorescent (UVF) image (Douma 2008). Similarly, infrared reflectography (IRR), thanks to the penetration of the infrared (IR) light beyond the pictorial layer, reveals under-drawings, as well as changes of mind (*pentimenti*) in the artist's intention when sketching the painting. The *pentimenti* are proof of spontaneity and genuineness that might not exist in forged paintings, which might be mechanically copied and devoid of out-of-the-line creative movements of brushstrokes (Djuric *et alii* 2018).

For structural analysis of the substrates of works of art, radiographies are a suitable technique to visualize the skeletons of ceramics and painting's canvases, due to the X-Ray absorption that varies according to the thickness and atomic density of a material (Newman, 1998, Riederer 2012). X-Ray images can reveal metallic structures used for reassembling torn ceramics (Berg 2018), stitches and sewing in canvas or panel substrates, and it can detect underdrawings as well as a hidden painting underneath the visible one (Tum and Middleton 2006). This last application is especially relevant for investigating forgeries, since historic substrates might be reused in order to trick the dating of the materials. As far as the substrate analysis go, X-ray determines the way a canvas is weaved and is an alternative to the manual "thread count" device (BBC 2019) used to detect the same source/provider of the canvas (Johnson *et alii* 2010). As an example, Erdmann *et alii* (2013) compared through computational analyses the weave patterns in all the three canvases from Poussin's Bacchanal series commissioned by Cardinal Richelieu in the 17th century. Out of the three paintings, only one, the Triumph of Pan, was formerly appreciated as authentic by art experts, while the others were, though not unanimously, perceived as copies based on stylistic inconsistencies and doubtful provenance (Erdmann *et alii* 2013). The computational analysis of the radiographs executed by Erdmann *et alii* (2013) showed

that all the three paintings belonged to the same bolt of canvas, indicating the authenticity of the full series. In the case of the Triumph of Silenus, this discovery was further supported by subsequent cleaning and technical examination of the painting (Whitlum-Copper 2021).

An extension of the radiographic technique is the Computed Tomography (CT), which instead of framing only a 2D image, captures the X-ray absorption of volumes and can then generate cross-sectional X-Ray images from that volumetric data (Bettuzzi *et alii* 2015). For art forgery detection applications, CT is especially informative for non-flat objects such as ceramics, sculptures, etc.

Continuing the line of "seeing the unseen", non-invasive imaging techniques are predominant in detecting primary inconsistencies (Simon and Röhrs 2018) and reveal information that is not visible to the naked eye with respect to the materials employed in a work of art. For example, multispectral digital cameras output a reflectance image for a limited number of bands (typically around 30 spectral bands) in the visible and invisible electromagnetic spectrum, can isolate restored or overpainted areas, and discriminate between paints with different spectral formulations but similar color appearance (Simon and Röhrs 2018; Hameeuw *et alii* 2017). Taking possibilities further, hyperspectral sensors (that can acquire hundreds of channels) allow the recovery of a spectral reflectance distribution of the studied material, which can become the signature of the painting materials, enabling the detection of anachronic pigments that determine a *"terminus post quem"* for the creation of the artwork. As a matter of fact, hyperspectral imaging in combination with classification approaches has proven effective for ink segmentation in old documents (Khan *et alii* 2018; Ciortan *et alii* 2015), craquelure pattern identification (Deborah *et alii* 2015), pigment mapping, as well as layer separation in Old Masters sketches (Polak *et alii* 2017). The benefits of image spectroscopy techniques as opposed to single-point spectroscopic instruments such as spectrophotometers is that instead of providing point-based reflectance measurement, hyperspectral techniques offer a spatial distribution of the reflectance curve under visible as well as invisible light (UV, near IR). In this way they present a map, a holistic image, that might prove very helpful for untying the knots in an art forgery case.

Whilst image spectroscopy can offer valuable clues and general overview, its interpretation is prone to the use of heuristics and thus contains a certain relativity in ascertaining the authenticity of some materials. Therefore, forensic art investigators must resort to more established, quantitative methods, that are also used in the field of art conservation diagnosis. X-Ray Fluorescence (XRF) and X-ray Fluorescence scanning are elemental techniques that output the chemical elements in a material with a high degree of confidence. The former is a single point of capture technique, while the latter provides an elemental map over a given area (Saverwyns *et alii* 2018). XRF is useful for identifying pigments in a work of art based on their chemical composition (Newman 1998). Alternative names for this technique in the literature are Energy-Dispersive X-ray Fluorescence (EDXRF) or Portable-EDXRF (Aydin 2014).

An important proof of authentication is given by dating methods. If a work of art is discovered to be anachronistic, then this is a convincing argument against its authenticity. Craddock (Craddock 2009) analyzes the major techniques for dating: radiocarbon dating (RC), thermoluminescence (TL) and dendrochronology. RC specifies the date when an organic raw material constituent of a CH artifact, not the artifact itself, has ceased to live. The underlying science gleans from

the measurement of one of the isotopes of carbon (carbon-14), which s present in all natural materials. Dendrochronology is the method of dating wood-based materials by assessing the rings in the wood's nucleus and it is often used for calibrating and validating the radiocarbon technique. TL dates the last time a material was heated. For this reason, TL is intensively used in investigating the authenticity of ceramics, by determining the time of manufacture

Recently, there has been a great development in affordable three-dimensional modelling technologies, including off-the-shelf digital sensors for acquiring the 3D shape of works of art (Karaszewski *et alii* 2012), as well as software that can create accurate geometric reconstructions and simulations. Some of the commonplace 3D acquisition methodologies are Structured Light (SL) scanning and Laser Scanning (LS) (Douma 2008). The development of 3D capture sensors is connected to the progress of 3D printing technologies, partly because the capture technology creates input models for the printing technology. While the benefits of 3D printing have been proven for the printing of medical prostheses (Li *et alii* 2017), it has also had a positive impact on cultural heritage through the creation of replicas that have educational, restorative (Ceccarelli *et alii* 2015) or demonstrative (Tissen 2020) purposes (for example, enabling the blind people to feel the topography of a painting). The flip side of the coin is the mass production of copies of CH artifacts, dangerous for the illicit trade of fake cultural goods: "Trade in faked antiquities is a potential concern given developments in 3D printing technologies." (Ireland and Schofield 2015).

2.2 Better Forgers

In discussing questions of research disclosure by art experts and conservation scientists faced with the professional intent of sharing their knowledge to bring advancement in their field and at the same time grappling with the danger of fraud and deceit, Craddock (Craddock 2009) opens the matter with a quote by Jack Ogden, reported in Beckett: "Do you risk educating forgers or having generations of ignorant museum curators?". Craddock continues by identifying four categories of knowledge that, if disclosed, can help the forgers in their fraudulent intents. The first one entails the correct materials and techniques employed in the creation of the genuine artifact. The second one refers to the scientific and other investigation methods by which forgeries can be uncovered. The third category comprises the knowledge behind natural aging processes and how their can be discriminated from the forced, artificial aging processes. Furthermore, the fourth class of risky information is comprised of the knowledge of how a copy can be adjusted to look like an original. Despite analyzing all these categories and providing many examples where the divulgence of such information has led to an increased number of forgeries on the illicit market, or making forgeries more difficult to unmask, Craddock concludes that information suppression is not worth it in the end and the balance of benefits tilts towards the detection of forgeries against the refinement of forgeries. In a nutshell, "one does not fight fraud with ignorance".

Nevertheless, one cannot deny the improvement of the forgers triggered by the improvement of sensors. The growing amount of knowledge on technology and its diagnostic potential is owed to the advancements of detectors and sensors. For instance, in the book "Art: Authenticity, Restoration, Forgery" (Scott 2017), Scott reports the findings of Stanish (Stanish 2009) concerning the forging of Peruvian pottery. As it seems, the Peruvian local community, who

were producing antique ceramics for commercial profit, had learned "by reading the right report" what carbon-dating does, and so they mixed in with the present-day clay some 2000 years old straws previously found in a nearby archaeological middens. In this way they managed to trick the RC. This trick would have been revealed immediately by a TL analysis, since the firing of the pottery was performed in current times, 2000 years later than the fabrication of the artificially inserted midden straw. Unfortunately, the cost of TL being much higher than RC and much higher altogether than the sell price of the so-called "antique" pot, nobody deemed it financially worthy to carry out the TL analysis. This is partly because "only in professional circles are these scientific tests (n.r.: TL) routinely employed because [...] the cost of ensuring material authenticity becomes prohibitive" (Scott 2017).

Other times, forgers rely on the limitations of the art forensic techniques and the weakness of the authority delegation mechanisms (see Section 2.3). A relevant case study in this sense is that of the forger Brigido Lara reported by Scott (2017). The storyline unfolds like this: Lara and his colleagues were arrested in the 1970s for looting ceramics characteristic of the Mesoamerican civilization Totonac. Archaeologists and art historians were convinced that the unveiled ceramics were originals looted from a Totonac site, even though Lara denied the looting and claimed that he was the craftsman behind the pottery. In planning his defense, when in jail, Lara asked for a chunk of clay, from which he made a Totonac-like ceramics. He asked for these "test" ceramics to be shown to expert archaeologists without them being informed on how, where and by whom it was created. On viewing the test ceramics, the archaeologists were once again deceived into giving the wrong verdict, thinking that the test ceramic created by Lara in the prison cell was a looted Totonac original. However, it was actually a fake, much like the ceramics that were previously considered looted. How could the archaeologists be deceived so easily? One answer is that Lara had been perfecting already at his forging technique. Nonetheless, to this deception also contributed the lack of certainty that could have been provided by TL tests. This lack of certainty derived from the material of the pottery of West Mexican area, that had in its composition volcanic minerals. Such volcanic minerals produce a saturated TL curve that makes it impossible to recover the normal clay firing signal (Scott 2017). In the case of Brigido Lara, both artistic and scientific connoisseurship have failed to detect the forged artifacts.

The Lara case resembles another story, that of the lost-and-found stone heads from some of Modigliani's sculptures. When two stone heads were found in Arno in the 1980s, renowned Italian art historians and sculptors - among them historian and writer Cesare Brandi, art historian Carlo Giulio Argan, sculptors Corrado Guerin and Carlo Signori - expressed their conviction that the two heads were authentic sculptures by Modigliani (Stobart 1984). In reality, it was a practical joke designed by Italian students, who themselves created the sculptures with the intention of mocking the easily deceitful art world (Stobart 1984), and who quickly acclaimed the bluff. Another forger with a sense of humour was Tom Keating (Magnusson 2006) who, when making pastiches of other famous artists such as Samuel Palmer, included clues such as contemporary messages, misspelled signatures and even distorted shapes that on closer inspection would reveal the fake in an almost obvious manner. This was in addition to the fact that he didn't employ historically accurate pigments. For example, in Keating's pastiche, "Sepham Barn" (see **Fig. 2**), misattributed to Samuel Palmer, a flying bat was eventually compared to a Boeing 707

during the 1979 trial R v. Keating (Grant 2015 p. 206), indicating negligent execution overlooked by the art dealer. Originally a restorer, Keating declared his intention was to mock the art market, not to deceive the scholars who would knowledgeably examine the painting (Grant 2015).

When the different expert authorities fail to reach an agreement between themselves, the third-party, in this case the forger, usually wins, at least in an incipient stage. An illustrative case where lack of consensus among expert authorities steered to omission of fakes is that of the forgers' couple formed by John Drewe and John Myatt (Carter 2007). They fabricated numerous forgeries, without even having considered the right materials or proper techniques. Instead, they offered the right provenance proof, since Drewe had access to the archives of main cultural institutions that he could tamper with, thus producing a fake chain of custody for the fake paintings (Sladen 2010).

Fig. 2. "Sepham Barn", as painted by Tom Patrick Keating. This painting was initially attributed to Samuel Palmer. In the trial R v. Keating (1979), the bats flying by the setting moon were infamously compared with a "Boeing 707" as a way to humorously criticize the art dealer who failed to notice the stylistic fake details (Grant 2015 p. 206). Image source: (Bonhams, 2007).

2.3 Authority Delegation

The hermeneutics of forgeries and authentication is very intricate, and this entanglement was visually described by a mind map (Buskes 2011) based on the considerations of Gladwell (2012) on impulsive versus considerate judgement concerning the matter of the fake Kourous that the Getty Museum had purchased. The map suggests a non-exhaustive screening process when studying the authentication of an art object, composed of six branches: checking the reasonableness of the price by comparing it to previous values listed on the art market; comparing style, colours and details to other object of the same category that were validated as being authentic; use carbon-14 dating; analyzing the materials, their origin and composition; have a collaborative judgment formed by a panel of experts and finally screening the sale records and the trustworthiness of the seller/auction house.

Overgaard *et alii* (2017) characterize the art market as subject to biased authority delegation, where "In essence, the art market community has delegated authority over the authentication of works of art to the art expert community. In doing so, the art market accepts the authenticity of whatever artwork is deemed authentic by art experts". They introduce two novel concepts of authority delegation that are supportive to the pluralism of stakeholders in the authentication studies: one-sided and mutual authority delegation. Simply put, the former concept purports that one community accepts the theory of the other while in the latter concept, both communities accept one another's theories on certain topics.

Craddock (2009) emphasizes that the stylistic analysis promoted by the art historians should be complementary and not in conflict with the scientific investigations. Nickell (2005) also encourages a multi-evidential approach in a study of authentication of written documents, where the evidence is fused from various sources, including provenance, macroscopic and microscopic study, spectral imaging and chemical examinations.

Personal beliefs and religious faith transform authentication studies from objective analysis to a subjective, emotionally based judgment that conflicts with authority delegation. For instance, art dealers might be so attached to an artist, that when they are faced with a forgery, their emotions stand in the way of a clear judgement: "It is a well-known phenomenon in the art world that a dealer or curator can become fixated on the idea that they discovered a long-lost work of a master. Once one has convinced oneself it is right, it becomes psychologically impossible to reject that conclusion and accept it is wrong." – Brian Sewell as quoted in (Grant 2015 pp. 210-211). Psychological bias of art dealers was a contributing factor in both Tom Keating's case (Grant 2015) and the Knoedler's Gallery case (Miller 2016), where art dealers were more inclined to listen to their own intuition rather than to scientific evidence. In an analogous way, the authentication of religious relics has been a controversial subject, prone to fierce and passionate debates (Nickell 2007). An illustrative case is the Turin Shroud, where the carbon dating of the textile proved that the shroud belongs to the medieval period as opposed to the hypothesis that stated it should be 2000 years old (Di Minno *et alii* 2016). Another relevant case is that of the "Dead Sea Scroll" fragments from the collection of the Museum of Bible in Washington DC, that after several suspicions raised by scholars and after a series of scientific investigations, have been revealed to be all forgeries (National Geographic 2020). This finding planted doubts about all the Dead Sea Scrolls fragments that have appeared on the antiquity market after 2002 (Davis *et alii* 2017) and as a consequence, multidisciplinary projects such as "The Lying Pen of Scribes" aim to continue researching on the authenticity of unprovenanced Dead Sea manuscripts (Agder 2019-2014.).

2.4 Towards Prevention of Forgery from an Ethical and Legal Perspective

According to the 1970 UNESCO Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Heritage Property (UNESCO 1970), cultural heritage is "one of the basic elements of civilization and national culture" whose authenticity and integrity needs to be protected and legally defended (Lagrange *et alii* 2018). However, UNESCO has a soft power in handling the local management against illicit trade at the

level of each member state that is responsible for the cultural heritage property on their territory according to their state jurisdiction. As a matter of fact, UNESCO compiled a database of the national laws useful to fight the illicit trading of cultural heritage property of the member states of the 1970 Convention in order to keep track of the similarities and differences between the national jurisdictions as well as the heritage under peril (UNESCO 2003) and push for international cooperation. For instance, in Italy, a dedicated body of the military forces was formed to be entirely dedicated to the supervision of cultural heritage trade: The Carabinieri Commando for the Protection of Cultural Heritage (Carabinieri 2017). Since 1980, the Carabinieri implemented a database to help them keep track of illegal records concerning the theft and commercialization of removed or fake cultural heritage goods. The "Database of illegally removed cultural artifacts" (Carabinieri 2017) has been an important aid for the Carabinieri in conducting a careful analysis of criminal phenomenon and enforcing the law concerning the illicit trafficking of cultural property.

Some jurisdictions are radical about the destruction of forged works of art as a measure to stop the contamination of the art and research even if this interferes with the property rights of the owner. Exemplary in this sense is the story of the fake Chagall (Herman 2014), seemingly entitled "Nude 1909-1910". The owner was a British businessman, who purchased the painting after the fall of the Soviet Union and, for this reason, the provenance of the painting in the last years prior to its purchase contained dubious and unclear details. The owner appealed to the help of the BBC's "Fake or Fortune" crew. However, all the local tests and experts were reluctant to vouch for the genuineness of the painting, so the owner decided to resort to the French Chagall Committee, the authoritative body on the painter's opus. The Committee denied the authenticity of the painting, judging that it was a copy of the "Reclining Nude". The consequences didn't stop with the verdict of forgery. The Committee and its members, out of which two are Chagall's heirs, wanted to proceed with the destruction of the painting and they had the support of the French law. More precisely, the moral rights of an artist, also called the inalienable rights are protected under the Intellectual Property Code in the French Jurisdiction. This however is clashing with the property law defended by the British jurisdiction, to which the owner of the painting is entitled. Philip Mould, the art dealer and cohost of the BBC series, argued against this "pro-destruction" verdict claiming that it is "anti-academic". Indeed, forgeries might have an educational, if not artistic, value and they can be secured as negative examples or as a threat to forgers, showing that even a "perfect" forgery was in the end possible to uncloak. For example, two of the Han van Meegeren's forgeries are on display in a side corridor in the Rijksmuseum (Essential Vermeer 3.0 2021), therefore not in a top location along with the genuine masterpieces, but admittedly exhibited as second-hand art as opposed to being hidden in a deposit.

Nonetheless, Craddock (Craddock 2009) reflects not without a note of disbelief upon the rate of success with which the conventions and international agreements such as the 1970 UNESCO convention have achieved to diminish the forgeries. The author is reluctant to concede that such movements have succeeded to "even slow down the growth in the international traffic in looted antiquities, much less stop it. Ultimately, the prices collectors and museums around the world have been prepared to pay are just too tempting.". He considers that forgeries are an evil that scholar need to fight by perfecting their knowledge and methods of investigations and by sharing these advancements with bona fide community, without being stuck in a stage of isolation and

ignorance provoked by the fear of forgery. The fear of forgery is a greater threat than the fear of legal action to the traders or illegal cultural property, because once the authenticity is questioned, rumours spread fast, the market collapses, and the prices become uninteresting or unworthy.

A simple conclusion of this essay might be that better sensors evolve along with better forgers. Primarily they push for better-quality, objective research and smarter detection of past and present forged CH objects, leaving less room for subjective and cultural or emotional-driven deceptions.

III. ART AUTHENTICATION IN THE DIGITAL ERA

The role of computational techniques and digital image analysis in forgery detection has grown so important that recently the term “computational connoisseurship” (Ellis and Johnson 2019) has been coined. Ellis and Johnson (2019) showcase in a non-exhaustive way four projects where digital tools showed a major contribution to art history and art attribution: canvas thread count automation project, historic photographic paper classification, chain line pattern marking and in paper drawings, and watermark identification in Rembrandt’s etchings. For this reason, the number of research projects dealing with digitization of cultural heritage collections has incremented in the past years. For instance, in (Lopatin 2006), the authors agree that digitization enhances the visualization of libraries’ collections, supporting the notion that “collections can be made accessible, via digital surrogates in an enhanced format that allows searching and browsing, to both traditional and new audiences via the Internet”. Such digital surrogates can represent a back-up solution for CH at risk. Recent armed conflicts in Syria and Iraq brought the CH to the battlefield, provoking direct or collateral damage to world heritage sites (Soderland and Lilley 2015). Furthermore, following natural disasters that are less controllable and preventable by human intervention, such as the 2019 fire at the Notre-Dame Cathedral in Paris (Metro Game Central 2019), digitization provides a memory of the heritage, offering the possibility to restore it as it was, if desired. This has been done in the past for the cities of Warsaw and Munich (Sorbo 2019; Bevan 2007). While a major purpose of digital surrogates is to document, monitor and improve the state of conservation, there are several less noble collateral effects, such as commodification of CH objects, and the generation of fakes and replicas. In this context, one possible prevention method lies in the separability of access to the CH repositories and expert knowledge.

Beyond documentation, many CH digitization campaigns are research-driven, where the main purpose is not solely the preservation of the object, instead it is the potential of novel sensing technologies to answer questions about the history, material, meaning, creative process and verisimilitude associated with a work of art (Books 2012; NTNU 2018). An important aspect of the research-driven digitization is the integrity is the integrity of the digital data, which may be subject to alteration as it can be altered either during the data capture process or in the post-processing stage via software tools.

This section starts with a polemic on the nature of the digitization process (subsection 3.1). The extent of standardization or creative input during the digitization procedure is a first

variable influencing the digital data integrity. Subsection 3.2 delves into post-acquisition aspects concerning digital data integrity and is followed by a discussion on data access (subsection 3.3). Ultimately, in 3.4, the concept of "reverse-engineered digitization" is explained and linked to the take-off of computational creative systems.

3.1 CH Digitization: A Mere Protocol or a Creative Process?

There are two main concerns when it comes to a digitization process: ensuring the safety and integrity of the CH original objects and at the same time, maximize the quality of the collected data. Hence, a big amount of work is tunneled to define quality standards by art curators, scientific experts, museum photographers and governance stakeholders in order to issue good practice guidelines for CH digitization (Still Image Working Group 2016; Digital Transitions 2019; Van Dormolen 2008). For instance, the National Library of Netherlands teamed up with the National Archives, under the coverage of the Dutch Ministry of Education, Culture and Sports and developed the Metamorfoze quality guidelines (Van Dormolen 2008), defined for the photographic digital reproductions of two-dimensional, paper-based artworks and split along three axes of quality depending on the rank of importance and complexity of the objects studied. The quality parameters are based on universal test targets, scanner reference charts and other test charts and gather criteria and tolerance thresholds for evaluation indicators specifying among others color accuracy, illumination, white balance, spatial resolution, and dynamic range. With the Metamorfoze imaging guidelines, the goal of the institutional triangle was to create a "Preservation Master ", which is the first file generated during digitization with a resemblance to the original as loyal as possible and used as reference for all other digital derivatives. Similar to Metamorfoze, the Federal Agencies Digital Guidelines Initiative (FADGI) Still Image Working Group from United States is another example of a collaborative approach channeled towards establishing instructions for ensuring the quality of images acquired in CH digitization campaigns (Still Image Working Group 2016). They adopt a four-tiered quality classification, building on top of the three-layered podium proposed by Metamorfoze. As a wrap-up of the combined efforts in this sense, the International Standards Office (ISO) proclaimed a new working group, JWG26 under the Technical Committee 42 with the scope to "unify metrics, related methods, and tools used to specify and measure image quality capability of systems for the recording and evaluation of CH materials for archival purposes".

However, it is not always the case that a collaboration between stakeholders exists so as to propose long-term, systematic decisions over fragmentary shortcuts in digitization projects and digital resource planning. A survey (Abd Manaf and Ismail 2010) based on structured interviews answered by three Malaysian governmental cultural organizations pointed out an insufficiency of cross-institutional collaboration which poses a risk for the national heritage because that "the implementation of digitization projects is piecemeal basis and their management may not facilitate structured implementation of the project [...] Collaborative effort and holistic approach across the three studied organizations are not present and they are not merging their efforts towards one common goal of preserving the national cultural heritage".

Another challenge of digitization projects stands in the know-how of handling the software and hardware behind sensing systems. As supported by Abd Manaf and Ismail (2010), a poor

knowledge of dealing with these systems leads to poor-quality data: “The quality of digital objects greatly depends on the staff expertise on utilizing the available technology”. Training is deemed to receive specific importance in the generation of research data and the research institutions are the ones responsible for filling in the knowledge gaps of operators working with on-site and off-site CH sensing activities mitigating this digital literacy risk in ensuring the quality and integrity of the scientific data produced (Kleppner 2009).

Beyond digitization protocols, the handling of hardware and software in art scanning operates partly in a space of subjective choices. How much creativity and subjectivity are undertaken, for example, by a museum photographer when digitizing paintings? To answer this question, a relevant case is the Bridgeman Art Library, Ltd. v. Corel Corp. court case (Justia US Law 1998), handled by the District Court of US. It is perceived as the pioneer case to have first created opposing parties among the experts, arguing whether digitization of the two-dimensional public domain artworks are mere “slavish reproductions” that lack sufficient creativity and originality to be entitled to a copyright of their own or they comprise minimal creativity so as to become copyrightable (Petri 2014; Kogan 2012). In the late 90s, the UK Bridgeman Art Library filed a lawsuit against the Canadian DVD company, after coming to knowledge that the defendant commercially distributed DVDs with two-dimensional images of artworks found in Bridgeman’s collection. Even though the paintings in the collection were appropriated to the public domain, the plaintiff claimed that their institution was the only one to have had access to perform full-fidelity reproductions of the artworks. Moreover, some of the paintings belonged to the Bridgeman’s private collection, to which third-party access was claimed to have not been granted at all, not even for the exhibition. Regardless of the lack of factual evidence that the photographs sold by Corel were the same as those produced by Bridgeman the library lost the case at any rate on the account that the photographs “lacked sufficient originality to be copyrightable under United Kingdom law**”.** In other words, they were considered mere faithful reproductions of the works of art, without adding novel elements of creativity so as to be deemed *de jure* originals, notwithstanding the position of those who opposed this decision, who are supporters of “the sweat of the brow” concept where technical skills and intensive labour behind faithful reproductions are worth of a *de facto* original work.

The decision in the Bridgeman case and the belittling of the digital reproductions of two-dimensional works of art by referring to them as “slavish reproductions” has generated a buzz in the literature of CH field. One of the reasons for this is the unclear bounds of the threshold of originality in the copyright law and the determination of the slavish copy, since they were first coined in the mid-19th century (Kogan 2012). According to the 1991 US Supreme Court Case Feist Publications, Inc., v. Rural Telephone Service Co. (Kleppner 2009), there are two criteria of originality: independent contribution to the work and minimal creativity “[T]he work [must have been] independently created by the author (as opposed to copied from other works), and... it [must] possess [] at least some minimal degree of creativity”. However, “minimal” does not eradicate the subjectivity to the notion and content of creativity. Perhaps it is this relativity that opened the controversies. To begin with, the law changes its judgement when pictures are taken of three-dimensional art items, as they are considered copyrightable, because the choice of angle and shoot perspective necessary for capturing a sculpture for example entails a minimal creative choice. At this point one might argue that the technical skill behind photography

is very similar regardless of the object having a more or less pronounced three-dimensional geometry and relief, and the reason why 2D-like objects seems more simple and less creative is simply the history and long practice of 2D photography as opposed to 3D photography. If the counter-argument is the fact that one photograph of a 3D object doesn't reveal a high-fidelity reproduction of the object, then does it mean that using a laser scanner that generates a 3D model and reconstruction of the object is the equivalent of 2D digitization of 2D-like paintings? These are all questions that, to the best of my knowledge, are not yet to be answered in the law textbooks and might point out some inconsistencies to the copyright looseness in the digitization of public domain artworks.

Kogan (Kogan 2012) revolts against this blurry threshold of originality that names a reproduction of a painting "slavish copy" and at the same time an amateur selfie with a painting, taken with a point-and-shoot camera, is deemed original and protected by copyright. The author believes that museum photographers should be given more credit and that museum's work in digitization of public domain artworks should not be perceived as a "copyfraud", instead it should be protected as an original work. One of Kogan's most powerful dialectics is the comparison of a 2D painting's digitization with a map instead of comparing it to a transparent window whose only purpose is to help the viewer peek into the initial creation of the artist - the way "ordinary viewers" such as the judges choose to see it. The author elaborates the map comparison putting it in balance with an aerial photo of a city: the same way the aerial photograph correlates each physical location and feature of the city into the image coordinate systems stored in photodetector's on the instrument's sensor, the same way a picture of a painting maps each visual attribute of the work of art into another coordinate system and most often this is not a one-to-one mapping. Kogan considers that both the aerial capture (actually, areal could be extended to the remote sensing field from which photographic techniques are often transferred and applied to CH digitization) and the reproduction of the painting are original work, not mere slavish copies. In his article, he brings arguments based on the philosophy of the photography and the cultural tendencies and habits of viewing photography as a mechanical reproduction, misconceived to be purely factual and truth to reality images, ignoring the creative choices that go beyond pure technical skills in acquiring photographs and that can play with light and shadow or color filters to impinge an artistic reinterpretation of the reality.

Kogan continues with debates from the visual arts, asserting that "many photographic attributes of a photographic reproduction—size, surface texture, interplay with light, etc.—are fundamentally different from the pictorial and painterly attributes of the depicted painting" and delineating the difference between photographic document and duplicate. While a photographic reproduction is a document of the painting, recording the existence of the painting, with high-quality equipment and trying to secure as truthful as possible the visual attributes of the painting, it cannot capture the exact appearance aspect and it is thus not an exact imitation or duplicate. He concludes that in evaluating the independent artistic contribution of Bridgeman's photographers, the judges fell in the trap of ordinary cultural habits, looking to the digitization as to see-through photographs and mistaking them for duplicates instead of "documents of the world" by overlooking the myriad differences between the painting and its digitization. In response to the critiques claiming that the digitization process is protocol-based and formulaic, where the same output can be repeated once the recipe and the ingredients are well-written, regardless of

the photographer's creative input, Kogan quotes from the working diary of a former photograph of the Metropolitan Museum of Art, Sheldan Collins - who, acknowledging the great complexity of CH digitization, agrees that a set of guidelines is necessary, however not comprehensive since a great deal of creativity, artistic style and self-expression is required for achieving excellence in the documentation: "Photographic technique easily blurs the distinction between the beauty of the subject and the beauty of its image. […] Insofar as the photo-documentation of works of art necessarily involves distorting and abstracting—lying and beautifying—it partakes of the nature of those higher art forms that comment on reality. Here we have a neat paradox: one potential art form—photography—remarking on another. It is like holding two mirrors face-to-face. But unlike a static mirror reflection, the photographic process has a dynamic mind controlling it, editing and selecting which "truths" about a work of art will be formed in the camera's ground-glass".

Nevertheless, by striving to prove the creativity of photographic documentations of CH and defend the ethics of the cultural institutions and the museum photographers, another aspect of ethics might be violated, which is the truthfulness of the images produced. As highlighted in Ireland and Schofield (2015), non-photorealistic renderings, interpretations, and visualizations in the process of digitization are looked upon as an unethical professional behaviour: "Trust, truthfulness and transparency are professional and ethical values. An opinion survey showed that local people trusted North American museums to be accurate and authentic. Ethical codes for archaeology, museums and archival practice stress professional obligations to retain and value authenticity and uphold intellectual integrity by separating factual evidence from interpretation and unfounded opinion.". Therefore, admitting that the digital images are too faithful to the original work of art trades their copyright protection, while pretending a high share of interpretative and subjective contributions in the imaging process might trade their ethical value.

3.2 Integrity of Digital Repositories

As defined in Pelagotti *et alii* (2020), integrity of digitized artworks implies that no creative choices taken in the acquisition process or in the post-processing stage significantly alter the data so that they result in a deceiving representation of the real object.

As introduced in the previous section, the separation between facts and interpretative choices during the acquisition process ought to be detailed in the metadata files that should accompany the images and other file formats generated during digitization. Metadata is "data about data" and it is crucial for the preservation of digitized CH, the verification of the data integrity and data stewardship, since metadata also includes the selection of the data types, file formats and the key to read and decipher these formats. In an overview about digital data aspects, Kleppner (2009) follow the definition of metadata provided by the sources of National Science Foundation Report on Cyber infrastructure Vision for the 21st Century: metadata "summarize data content, context, structure, interrelationships, and provenance (information on history and origins). They add relevance, purpose to data, and enable the identification of similar data in different data collections."

Metadata enables data users to navigate machine-readable data and in the case of CH databases, they can retrieve similarities in the CH collections, filter and display them by user-

selected criteria and draw research conclusions faster than in traditional source browsing. Metadata can be useful when format migration needs to happen or when parties other than the digital data patron and creator need to work and parse the meaning of the images, a situation quite common in interdisciplinary and multi-partner CH projects. Some digitization experts prefer to make a distinction between metadata - description of the raw data - and paradata - annotation of the processed data (Bentkowska-Kafel *et alii* 2012), as the main byproduct of digitization consists in the analysis and visualization of different layers of data and extracted information. In this sense, proposals have been made towards an exhaustive metadata model where the intermediate computational data and the software used for the simulations should be stored together with the data and their descriptive files (Kleppner 2009). This is in line with the FAIR principles (Hagstrom 2014) drafted by the European Commission (2019) and suggesting that the CH databases should meet the following adjectives: Findable, Accessible, Interoperable and Re-usable. Special attention needs to be given to the metadata of the physical object that is being digitized as this metadata is usually associated with the valuable clues related to the provenance of the work of art and the provenance is often considered as legal evidence in art forgeries determination (Carter 2007). Metadata is for the digitized archives what the physical archives of provenance are to real artworks. And like the faked physical archives in John Drewe's case (Sladen 2010) previously mentioned in subsection 2.2, the digital metadata files run the same or even greater risk of being altered as the physical records.

Art diagnostic evidence in the form of images is prone to malicious post-processing techniques that can alter the original digitization to support or dismiss attributions, as shown in Pelagotti *et alii* (2020). In fact, the manipulation of digital images is of interest to and highly debated by the general scientific research community. In the majority of cases, researchers might alter their data only to "beautify" its presentation in scientific publications, without openly mentioning it and therefore, deceiving the reader. In the minority of cases, images suffer severe manipulations regarding their content in order to falsify results in favour of the research performance. For these reasons, a set of 12 ethical guidelines has been proposed in 2010 by Cromey (2010), which draws the line between what is appropriate and not in the manipulation of scientific digital images. In order to ensure truthful and credible pixels, this ethical code recommends among others: the storage of the untouched original file, the use of lossless compression file formats and the avoidance to use operations such as cloning to obscure local imperfections of the image. What happens though when this code of ethics is broken, when the traces to the original image are lost, and so there is an interrupted *chain of digital custody*? Pelagotti *et alii* (2020) proposes the application of multimedia forensic tools on X-ray and Infrared art diagnostic images to retrace any retouching performed in post-processing. This approach assumes that forensic algorithms can decode any manipulation and provide a timeline of changes with respect to the original image through the computation of several computer vision descriptors that quantify entropy at various levels. To test this method, the authors artificially simulate *pentimenti* digital images of two paintings by El Greco and Pietro Novelli, using cloning tools like in image editing software where regions in the image can be copied and pasted at another location in the image. Notwithstanding a preliminary study, Pelagotti *et alii* (2020) managed to detect the tampering with some of the tested forensic tools.

3.3 Levels of Access for Digital Repositories

As regards the access to the repositories of digitized images of CH research projects, one of the main challenges is how a middle way can be reached between the two extremes: the first one is the choice of full data retention, completely hiding the digital data, without enabling the scholarship to examine it and thus hindering what could potentially be an advance in research and the second one is unrestricted open access to high-quality data without any thought of the background and intentions of the party who might access it, nor if such an access can open a path to further derivative works done in perhaps bad-faith by ill-disposed entities.

The drawback of the first approach is obscuring the transparency of the research projects, that could lead to unchecked and unverified data and other errors that might arise due to the blindness of single-minded or single-grouped research. This is an obstacle for ensuring data integrity. A good research practice would be to have continuous and if possible external other than internal peer-reviewed feedback on the research data, its processing, analysis and the computing of the results. One could argue that external peer-review is achieved by means of scientific publications, yet few publishers have developed a protocol for the upload of supplementary material and a method to check its verisimilitude or correctness. Developing such protocols would avoid situations where researchers "willing to share their older information online will not release more recent or current information due to business competition. Others may not wish to draw public attention to substandard work produced under commercial pressure of development-driven archaeology. Fear of 'airing dirty linen in public' inhibits information sharing in archaeology elsewhere and in other disciplines. Most of us want to showcase our better work." (Ireland and Schofield 2015). Participatory design principles and agile design methodologies, where "technical and project managers work closely with clients, users and other stakeholder in an iterative manner so that consultation, testing and feedback are automatically incorporated into the design and development process" are encouraged in CH project and considered as ethical professional behaviour (Ireland and Schofield 2015).

On the other hand, the second extreme approach is risky if knowledge gets on wrong hands and an example in the case of CH, would be the use of knowledge to create forgers and trick the detection systems. The same way some researchers are embarrassed to make low-quality data publicly available other researchers might want to boast their high-quality experiments and results as measure of the quality of their research and hence, as recognition of their success: "Evidently, successful digital projects are the result of not only consistent high-level image quality, but also convenient access to these digital images through the facilitation of appropriate procedures and accepted standards." (Abd Manaf and Ismail 2010).

However, one shouldn't fall into the illusion of pride of high-quality image, nor in the caves of deception provoked by bad results and publish their research results on different levels of representation corresponding to distinct levels of expertise of the intended audience that has or can deal with the data and applying protection measures accordingly. For instance, in case of online repositories, such protection measures can vary from the specification of licenses where rules on how to use the data are negotiated into a legal-binding contract, to password-protected data or to the requirement of user registration as a way to inspect and validate the affiliation of the user and discover whether the intentions with respect to the data are under fair use principles to

developing smarter technologies that impede harvesting and data mining (Ireland and Schofield 2015) unless for a good research-oriented cause.

Drawing from the ethics of heritage conservation, public ownership and open-access are promoted and the righteousness of the public is "tempered only by consideration of privacy, confidentiality of commercial information and cultural rights of traditional owners and descendants" (Ireland and Schofield 2015). From an ethical point of view, access to CH research data should be restricted when it includes sensitive information about a specific group of people and their culture (Nicholas and Egan 2012). This is especially relevant for indigenous, community-based cultural heritage: "Ethical technologies could be, for example, web pages that allow users to view but not download, copy, alter or redistribute digital assets or which restrict access to online information deemed culturally sensitive." (Ireland and Schofield 2015). As an example of an ethical webpage, the National Centre for Research and Restoration in French Museums showcases several works of art on a webpage (C2RMF 2021), where the viewer can see a painting in high-resolution and can browse through its multispectral channels (Aitken *et alii* 2007), but without being able to download the images. Likewise, the BOSCH project allows zoomed in visualization of details in the paintings of Hyeronymus Bosch scanned at high resolution, disabling the possibility of downloading the pictures from the website (Erdmann *et alii* 2010).

3.4 Reverse-engineering Digitization

Access to digitized works of art raises the risk of them being replicated and manufactured into real objects. This can be seen as a reverse-engineering digitization process. A relevant case of reverse-engineering digitization that has got legal attention is Roger v. Koons court case (Artist Rights 1992; Copyright in the Visual Arts 1992). The artist Jeff Koons drew his inspiration from a black-and-white postcard copyrighted by the photographer Rogers and enacted the subjects of the postcard - a couple holding many, seemingly lookalike puppies - by ordering his craftsmen to transform the photograph into a sculpture (see **Fig. 3**). He designed the sculpture without crediting the photographer, who, in his turn, filed a copyright lawsuit against Koons. The plaintiff won on the ground that the sculpture was an exact imitation of the photograph, especially because of being a copy of the artistic expression. Koons claimed in his defense that he brought his own artistic contribution and stylistic changes in designing the sculpture (color, decorations) and that also his purpose was an intellectual concept devised by himself, that of making a parody of the commodification of society. In spite of the defendant's arguments, the court deemed that Koons acted in "bad faith" in pursuing an enactment of the photograph.

Fig. 3. A reverse-engineering digitization case. Left: Photograph captured by Rogers. Right: Rogers photograph enacted into a sculpture by artist Jeff Koons. Image source: (Copyright in the Visual Arts 1992).

The reverse-engineering digitizations have the potential of becoming more widespread now that the technologies that facilitate the creation of digital art are getting more diversified and advanced.

The project "Next Rembrandt" (Microsoft, ING 2016) had the goal of resuscitating Rembrandt's style, by creating *ex-novo* a computer-generated painting in his style. By implementing various artificial intelligence (AI) based algorithms, scientists were able to determine the most common subject in Rembrandt's painting (masculine portrait), and to extract common geometric proportions as well as color palette. Based on these features, a new, unseen portrait in Rembrandt's style was generated, 3D printed and exhibited in physical format (Microsoft, ING 2016). More recently, Yaniv *et alii* (2019a) created a dataset of artistic faces, by detecting and studying the landmarks of faces from existing artist portraits. Starting from the original faces, they augment the dataset by inserting variations in artist-specific facial proportions that modulate the level of abstractness of the portrait from very realistic to very artistic. One of the results of their method is the generation of average portraits (see **Fig. 4**) given a certain artist (Yaniv *et alii* 2019b).

In the above-mentioned cases, handcrafted machine learning techniques were used to computer-generate artworks where the important features to be extracted were user-defined. In contrast to traditional machine learning, deep learning methods identify the features in an automatic way that mimics the neural brain activity. The case of Edmond de "Belamy" artwork (see **Fig. 5**) has created a precedent of a digital-born artwork that was generated with a deep learning algorithm and was printed on canvas by a collective French artist group, called Oblivious.

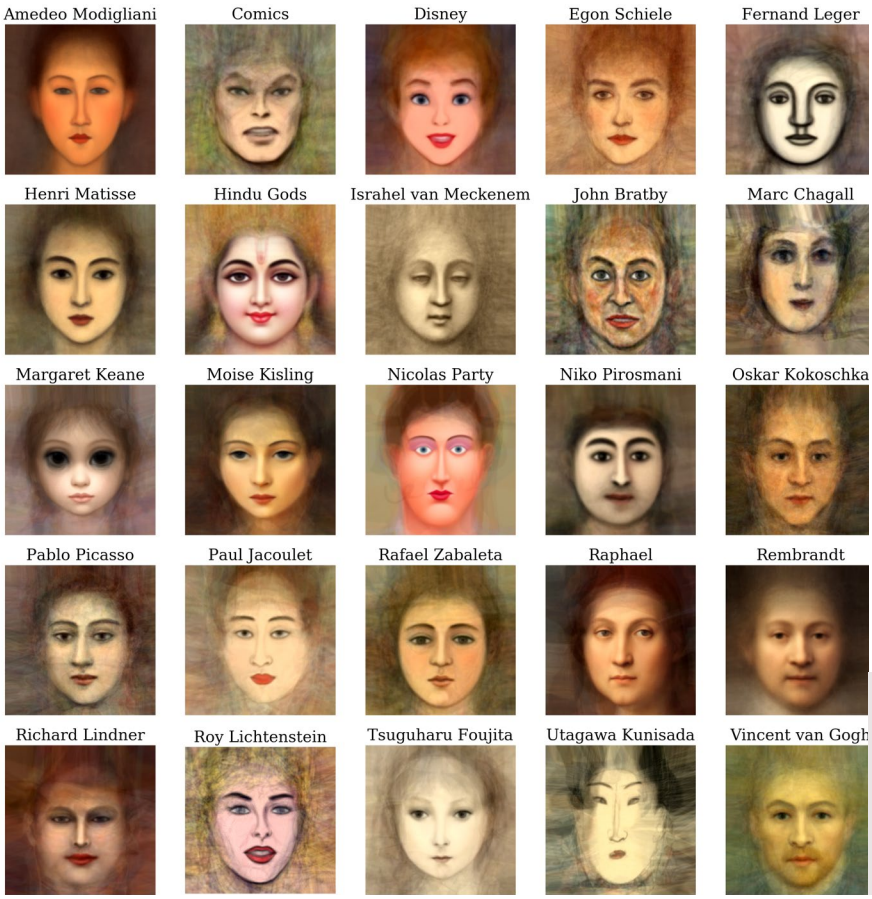

Fig. 4. Average portraits created by computing the average facial shape and color for various artists included in the work of (Yavin *et alii* 2019a). Image source: (Yavin *et alii* 2019b).

This artwork has unfolded many controversies. To begin with, it was sold at Christie's Art Auction in 2018 at an exhilarating price of $432,500. Then, its authorship is very ambiguous, as debated in (Epstein *et alii* 2020). The backbone of the artificial intelligence algorithm that was used for generating the digital portrait is called Generative Adversarial Networks (GAN) and was proposed by Goodfellow *et alii* in 2014 (Goodfellow *et alii* 2014) with the purpose of creating *ex novo* realistic-looking images. When these synthetic images represent human appearance, they carry the name of "deep fakes".

GAN is a deep learning method, that consists of two convolutional neural network submodules: a generator and a discriminator. Given an input dataset, the generator's objective is to concoct new, unseen data that has the same statistics as the input. In the case of visual data, the discriminator's role is to detect that the images fabricated by the generator are fake and are not part of the original input dataset. The two submodels are trained in parallel and learn from each other in an adversarial way, perfecting their game until the generator creates images that the discriminator fails to detect as fake.

Interestingly, the logic that stands at the core of GAN's development (and other related methods) matches the underlying thesis of "better sensors, better forgers" of the current essay. As described in the original GAN paper (Goodfellow *et alii* 2014): "The generative model can be thought of as analogous to a team of counterfeiters, trying to produce fake currency and use it without detection, while the discriminative model is analogous to the police, trying to detect the counterfeit currency. Competition in this game drives both teams to improve their methods until the counterfeits are indistinguishable from the genuine articles".

Building on GAN, Radford *et alii* (2015) implemented a network with a certain architecture, called Deep Convolutional GAN (DCGAN). AI-artist Barrat (2017) trained the DCGAN model on images of Renascent paintings, which resulted in the portrait that is mainly the base of the "Edmond Belamy" print. Arguably, the contribution of the Oblivious collective artist (the ones who go the full credit and financial remuneration) consists in selecting that specific artwork from a pool of other options, preparing it for fabrication, actually manufacturing it and marketing it. Furthermore, the authors of Epstein *et alii* (2020) claim that the success of "Edmond de Belamy" is highly linked with the anthropomorphization of the AI which inoculated the idea that the AI system acted on its own, while discarding the intellectual work behind the design of the algorithm or the creative choice of configuration and dataset to tailor the system to art-creation. By carrying out several vignette experiments, Epstein *et alii* (2020) found that participants were inclined to a distributed authorship, giving credit to all the intermediate parts involved in the process that led to "Edmond de Belamy" as final product.

One might expect that "Edmond de Belamy" is only the first artworks of the many to come, that will write the history of AI-generated art. As a matter of fact, building on GAN, Elgammal *et alii* (2017) invented a new computational creative system to generate art, called Creative Adversarial Network (CAN) (Elgammal 2020). This method models two factors that make novel art attractive as explained by Martindale's psychology theory: a new art-piece needs to be original and surprising enough so as to contrast with the old, but at the same time this increment in contrast with the old needs to have a maximum bound so as not to generate discomfort. CAN has created art that was deemed indiscernible from that of contemporary artists, as

appreciated by human subjects in a visual Turing test. Mazzone and Elgammal (2019) discuss the potential of the new wave of AI-enabled art and share success of exhibitions of artworks designed by CAN system. Indeed, in 2021, several AI-art exhibitions were organized that featured: GAN generated paintings of horses (Fire Station 2021), which are a metaphor of the universal need for persistence and resilience during the covid-19 pandemic (James, Sheng 2020); AI-art that transcends visual arts and incorporates music as well (NVIDIA 2021); cross-media artworks that use various computer vision techniques (CVPR 2021). An innovative exhibit at GPU Technology Conference 2020 (NVIDIA 2021) was that of the artist collective Oxia Palus (2021) who proposed a digital reconstruction of Leonardo Da Vinci's "Virgin of the Rocks" (see **Fig. 6**) by translating X-ray images to paintings, thus exploiting multispectral images that are otherwise used for forgery detection towards an artistic restorative endeavour. Oxia Palus (2021) reinterpreted other two lost masterpieces with their multidisciplinary approach: Picasso's "La Femme Perdue" and Rusiñol's "Parc del Laberint d'Horta". The latter is on display for purchase at Morph Gallery (2021) for approximately $11, 000. On the Morph Gallery's (2021) website, the *modus operandi* of Oxia Palus, that is "to combine spectroscopic imaging, artificial intelligence, and 3D printing to actualize the *pentimento*" with the purpose "to recreate exacting homages to a new breed of fine art" is described as the "NeoMaster Style".

Fig. 5. "Edmond de Belamy" (print on canvas). The first deep learning generated artwork, sold in 2018 at Christie's Art Auction for $432,500. The print generated many controversies regarding its righteous authorship. It is a born-digital artwork reverse-engineered to a tangible object. Image source: Wikimedia Commons. The image belongs to the public domain "because, as the work of a computer algorithm or artificial intelligence, it has no human author in whom copyright is vested".

Fig. 6. The digital resurrection of Leonardo da Vinci's "Madonna" as portrayed by the artist collective Oxia Palus. The painting was created using deep learning algorithms, X-ray images, edge and color maps, style transfer, and manual editing. It was exhibited online at GPU Technology Conference 2020 Image source: (NVIDIA, 2021).

Floridi (2018) highlights the dangerous potential of digital technologies in trespassing authenticity and in producing fake works of art. In addition, he debates the importance of nomenclature of AI-generated artworks and proposes the name *ectype* to define the "Next Rembrandt" (Microsoft, ING 2016). The etymology of the word is Greek and refers to a copy that remains connected to the original because they both share the same archetypal source. Floridi (2018) implies that there are two faces to an *ectype*, original source and production, and that they can be in turn authentic or fake. Following this rationale, he states that the "Next Rembrandt" is an ectype with inauthentic source, but with genuine production. What about the *neomastic* process of Oxia Palus (Morph Gallery 2021) – are the resurrections of lost masterpieces with (partially) authentic source and authentic productions *ectypes* as well? How much of the original source is preserved and how much creative content is added to these lost art reconstructions? Probably, future research and debate will make way for answering these questions. Nonetheless, while envisioning the future in the light of the digital era, Floridi concludes that even though "digital technologies seem to undermine our confidence in the original, genuine, authentic nature of what we see and hear", at the same time "what the digital breaks it can also repair, not unlike the endless struggle between software virus and antivirus".

IV. DISCUSSION AND CONCLUSION

This essay has explained the adversarial relationship between forgers and sensors. In a broad sense, the word "sensors" refers to the full set of technological tools employed by art authentication experts to help them gather evidence for a verdict. The digital backdrop and the wave of AI-enabled art raise many anthropological, political, ethical, legal considerations but at national and international levels. The plethora of advantages that technology can bring to the conservation and preservation of CH is undeniable, but it doesn't come free of side-effects that need to be regulated by clauses, conditions and efforts. Researchers and all the CH stakeholders, including the community spaces, need to commit to upholding digital data integrity, by respecting ethical and legal norms with respect to data collection, archiving, access and stewardship. In their work, pursuers of digital CH projects need to discern between *bona fide* and ill-disposed practitioners and share their research outcomes according to established hierarchies of privacy and expertise of involved third parties. The fabrication of art using computational creative systems, in particular the systems based on Generative Adversarial Network algorithms open unexplored considerations for art authentication and attribution. GAN algorithms are actually inspired by the principle of "better sensors, better forgers" and their potential in producing artworks that are considered by human viewers as painted by artists has already been proved. These methods have prospects as well in the CH reconstruction. The subject of AI-enabled art restoration and triggered ethical issues would be a major topic in itself, that would definitely be worth looking into in the future. In conclusion, this essay brings the following contributions to state-of-the-art: 1) presumably, it is the first attempt to make the analogy between an adversarial process from the machine learning field and the relationship of sensors and forgers from authentication studies; 2) it presents an overview of acquisition, integrity and access of CH digital repositories; 3) it introduces the concept of "reverse-engineering digitization" and anticipates the importance of AI-enabled art for matters of art forgeries and attributions.

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