ANALYTICAL-DIAGNOSTIC AND COMPUTING TECHNOLOGIES FOR THE ATTRIBUTION, AUTHENTICATION AND ECONOMIC EVALUATION OF ART WORKS

Salvatore Lorusso•
Dipartimento di Beni Culturali
Alma Mater Studiorum Università di Bologna (sede di Ravenna), Italy

Vincenzo Barone
Scuola Normale Superiore di Pisa, Italy

Lucio Colizzi
Centro di progettazione, design e tecnologie dei materiali (CETMA), Brindisi, Italy

Cosimo Damiano Fonseca
Accademia Nazionale dei Lincei, Roma, Italy

Keywords: work of art, reproduction, authentication, economic value

1. Premise: cultural heritage as economic and social capital

In considering the valuation of the cultural heritage of a country, it is usual to view the actual nature of heritage only as an economic asset, while its relationship with development also involves its ability to contribute to building social capital, that is to say, the political community of a country: hence, the identitary function of cultural heritage. In this respect, 'economic capital' and 'social capital' can be considered interchangeably or more aptly, starting points for taking appropriate action, given the grave situation that exists in Italy today regarding the conservation state of its heritage.

Indeed, there are whole pieces of Italian history that are falling to ruin and will eventually vanish forever.

The reasons are many and varied:

- the ignorance of public authorities;
- the inability to plan adequate protection and valorization;
- the lack of public funding;
- an obsessively pro-statism culture which is anti-historical and hostile toward any private sector intervention in Italian heritage, with the possible prospect of mixed private-public use under the vigilant eye of the state.

Moreover, Art. 9 of the Italian Constitution states, "The Republic promotes the de-

• Corresponding author: salvatore.lorusso@unibo.it

velopment of culture and of scientific and technical research. It safeguards landscape and the historical and artistic heritage of the Nation" (see "Constitution of the Italian Republic", *Senato della Repubblica*), which evidently means that fostering and developing community culture is one of the essential tasks performed by the state. It is primarily into this context that the protection of the landscape and historical and artistic heritage falls, implying that its safeguard goes beyond any sort of financial valuation.

Besides, as well as being protected by the constitution, Italian cultural heritage is for the most part inalienable and consequently of inestimable value because it is immense, but at the same time worth nothing, since it has no market. Part of this immense and non-pecuniary value is social capital – represented, for example, by that particular basilica, in the historic centre of that particular city and belongs, first and foremost, to those citizens who helped build and preserve it.

In the "*fabbriccerie*" – among the institutions that take care of the administration of religious assets, such as churches, and see to their conservation and upkeep - that preserve and maintain these historic buildings and architectural complexes, there are representatives of the church, state and territory.

This initial premise introduces the more specific issue, discussed below, of establishing the economic value of art works in relation to their attribution and authentication.

2. Formulating the economic value of art works

To formulate the economic value of an art work it is first essential to define and understand what a work of art is. An outline should therefore be laid down which includes the following phases:

a. define what a work of art is;
b. understand what a work of art is;
c. give an economic evaluation of the work of art.

a. Defining a work of art

To define what a work of art is one needs to ask the following questions:

- Are the works of art recognized on the basis of specific properties?
- Are they such because *we* decide they are or because the *experts* decide they are or *they are* nonetheless, regardless of any other considerations?
- Are they considered works of art at all times or are they only such by virtue of historical and cultural conditions or because of technological circumstances?
- Can works of art be replicated as wished or must they be original and unique?
- Are they a pure luxury or is the need for art a basic need of human beings?

These questions are typical of what is called in philosophers' parlance the 'ontology of art', in other words, the commitment to define what kind of object it is.

In this context, the distinction between objects of ancient and modern art is fairly clear: objects of ancient art can be appraised for their aesthetic properties; works of modern art can be appraised for the meanings they represent for a community.

The most recent evidence of this trend is the conceptual art of the twentieth century, whereby anything can be a work of art, provided that a community, or a group of peo-

ple, or at least its author considers it such. It is also true, as Umberto Eco claims, that a contemporary work of art is an “open work”, but equally true that its interpretation does inevitably have its limits. These limits are represented by human beings: that is, by the human ability to perceive things in terms of time and space. In light of these limitations, however, criteria may be provided, albeit minimal, for defining the necessary, but obviously insufficient conditions, to evaluate a work of art; they are as follows:

- Works of art are, first of all, physical objects, in spite of the fact that in conceptual art, art and reality are spoken of as complementary fantasies.
- Art has to do with ecstasy, with feelings, – this is not an opinion, but a fact – which anyone can experience when they try to replace the vision of a painting with a story of the painting or likewise replace a poem with its paraphrase.
- Works of art are social objects: it would make no sense to talk about art with people who do not share our culture or similar cultures.
- Works of art only unintentionally transmit knowledge: it is true that there are works of art that may have a cognitive scope, but it does not in any way mean the primary function of art is the acquisition of knowledge.
- Works of art inevitably provoke feelings and emotions.
- Works of art are given a human character: judgments made about them are similar to judgments made about persons.

We may like or dislike all the objects, products or events we have to deal with every day. Some are evaluated for their beauty, others for their ugliness and others are not evaluated at all. Few of these items however, that appear either beautiful or ugly or leave us indifferent, are in the end called works of art.

The above words carry with them a value judgment: we do not acknowledge the status of work of art for all paintings in the same way and with the same certainty. The description could be used not only in a non-judgmental way, but in a purely descriptive way, so that a work of art may refer to any object made in traditional art, but this interpretation is just as problematic as the evaluative one. Those that are defined works of art, in effect, differ quite markedly from each other. A small part of them are found in museums, but museums too, contain heterogeneous objects. A work of art may be composed of sounds, colors, words, stones, images of all kinds, gestures and even objects or products that are, to all appearances, no different from objects in everyday use. It would seem then, that works of art have neither any visible characteristic nor any function which groups them together. Their heterogeneity is clearly evident:

- some works of art evidently require great technical ability, but not everything that requires technical ability is considered a work of art and not all works of art are difficult to produce (I could have made that myself!);
- some seem to reproduce things recognizable in real-life, others seem to reproduce things that are unrecognizable;
- some retain all the value that is acknowledged them, even when they are reproduced in large numbers, while others lose their value if they are not the original itself; some immediately amaze you and arouse your admiration, while others are totally incomprehensible;
- some are clearly quite beautiful, harmonious and enjoyable, while others are ugly, seem dissonant and even troubling, but in the end may remain in our memories.

In the last century the most diverse things have entered art history without possessing even the minimum characteristic for being called works of art in their own right, with

their own meaning or with their own duration (body art, land art, performances). Faced with these manifestations, there is always someone who will ask: but is this still art?

The question is by no means an unreasonable one. But a problem arises: the question assumes that we already know with some clarity what a work of art really is and a doubt only crosses our mind when considering an unexpected or provocative work of art, or an unintelligible event. But are we sure we know what a work of art is, even in its canonical significance? For example, are we certain we know why a painting (the Mona Lisa by Leonardo da Vinci) or a sculpture (the Rape of Proserpina by Bernini) are works of art? Yet who would deny they are?

A work of art, according to Heidegger, is the truth put into a practical form by representing a historical passage of history, thus, the display of a world on which man bases his living and his land [1].

b. Understanding a work of art

To give a value to a work of art, potential analytical methodologies must be outlined, aimed at evaluating the aesthetic and communicative qualities of the art [2]. The basic tools used for interpreting them can be summarized based on the following studies on:

- structuralism and semiotics (the work of art is a communicative object composed of signs that operate in a figurative context and in a cultural environment);
- psychology of form (figurative art is primarily a composite image of structures that reconstruct models in one's mind);
- iconology (iconographic expression determined by a cultural model);
- psychoanalysis;
- history;
- sociology (art as a social issue has its foundations in the specific field of figurative languages);
- rhetoric (in its overall communicative objective, the figurative element also acts as an element of persuasion, advocate of controllable effects).

Hence, to comprehend a work of art, it is necessary to evaluate a series of paths which lead to understanding the work of art. These include:

- a semiotic and structural path;
- an iconologic path;
- the work of art as a document – analysis of detail;
- historical path: history of the motivation;
- analysis of the artistic movement;
- psychological/cognitive path;
- psychoanalytic path;
- uniqueness/reproducibility.

c. Economic valuation of the work of art

There is no doubt then, that the holistic value of a work of art is characterized by a set of values concerning different areas of investigation:

- cultural value
- historical value
- aesthetic value
- artistic value

} **Historical-humanistic area**

- spiritual value (in the event of works with religious significance
- symbolic value
- social value (the work of art gives a sense of identity)

Philological-philosophical social area

- technical value
- economic value
- financial value
- commercial value
- marketable value

Technical-economic-management area

- value of authenticity (if the work is authentic, it is a value in itself which is added to the others)
- value of identity
- value of interdisciplinarity
- value of internationalization

Legal-identitary area

On the matter of the holistic value of an art work, which in itself should contribute to determining its specific economic-financial-commercial-marketable value, it is worth pointing out that no official body exists in the Art Market which is able to provide market quotations for artists' works. There are however, several reference points that help define quotations and keep them updated. They include art galleries, auction houses, fairs/markets, catalogues, yearly reports and the latest internet sites offering this service, often for a fee [3].

One method of calculation used for two-dimensional painting is that of the coefficient. For each artist there is a corresponding coefficient which can vary from 1 on. This coefficient is then multiplied by the sum of the dimensions of the painting – for example, a painting measuring 400 x 600 mm, by an artist with a coefficient of 5, will be quoted at 5,000.00 euro (400 + 600 mm x 5).

In reference to the above, below is a summary of the factors enabling the economic value of art works to be formulated, some attributable to the author and others to the work.

Among factors attributable to the author are those that determine the artist's coefficient:

- the importance of the gallery that represents him;
- the importance of the critic who writes for him;
- the importance and the number of solo and group exhibitions;
- the display of his works in major events, exhibitions and public institutions;
- the publication of his works in catalogs and art books;
- the presence of his works in important public and private collections;
- any prestigious prizes or awards received by the artist.

To these are added factors which are more closely linked to relational aspects concerning critics, institutions and collectors:

• the artist's inclusion in an art movement;
• the historicism of the movement;
• the author's nationality.

It follows that the system assigning artists their value is a system of closely-knit relations. The critic will be important if he works with major galleries and well-known artists. The gallery owner will be influential if the artists presented have had public recognition from institutions and museums, as well as being part of the private collections system. The collector will influence an artist's success, if his collection is rich and representative of a particular period or artistic movement and if his works are made public, at least through loans to exhibitions [4].

Among the factors attributable to the work are:
• the subject;
• the time of its execution during the life of the author;
• its uniqueness;
• its history;
• its state of conservation;
• events related to the work;
• its size.

As a result, in the event of a forgery, the forger's interest will usually target artists with a high coefficient, reproducing works from a given period of their lives.

Although connected to certain conditions and situations, which are certainly not evident unless they fall into the category of uncertainty and unpredictability, the multiplicity and variety of factors can nevertheless contribute to determining the price of the art work, also on the basis – to be considered the fundamental starting point to refer to – of the subjective and objective evaluation of its authenticity [5-10].

3. The forgery of art works

There is no doubt that the foregoing is closely linked to and dependent on ascertaining the authentication or falsification of the art work, specifying however that the price is what one pays and the value is what one obtains.

The forgery of art works is a serious problem for the art market. The percentage of inauthentic art on the market is very high. The *Comando Carabinieri Tutela Patrimonio Culturale (CCTPC*) – the Italian police department for the protection of cultural property - claims the number of fakes sequestered is constantly increasing. Figures for 2012 were 4,111 with an increase of 1.6% compared to 2011 with a figure of 4,046 [6].

This phenomenon particularly affects the sector of contemporary art, given the relative ease with which works from this period are reproduced – namely abstract or conceptual works – and the growth in their market value; in fact, about 75% of art crimes involve objects belonging to this historical art period.

Certification of these works and/or its publication in the artist's general catalogue is therefore essential for the market and in some cases is more important than the art works themselves. This is the case for Tancredi Parmeggiani for example, whose abstract works are sold only if published in the general catalog. This situation creates a paradox however: works that are actually authentic, but not catalogued, are thus treated as if they were fakes. On the contrary, fakes have been

found in general catalogues that have, however, retained their commercial value.

There are a number of well-known cases, where works, for a long time believed to be authentic and exhibited in major museums, have eventually been revealed to be fakes at a later date. The following are two recent examples:

- at the Victoria Museum in Melbourne, the work known as "Head of Man" exhibited as a Van Gogh for 67 years, was revealed, in 2007, to be a fake made by an unidentified artist, a contemporary of Van Gogh;
- three paintings by Marc Chagall ("Portrait of a Woman", "Family" and "Fiddler") were removed from the exhibition at the Suntory Museum of Osaka because they were found to be forged works.

Of course, forgers and counterfeiters have always existed. All the Old Masters had among their pupils those who could, in the future, copy originals. Guercino is a well-known example. He actually declared in his diary that he had put his signature on several paintings produced by his workshop. There were also artists who re-proposed their works after many years. Giorgio De Chirico perhaps the greatest forger of his own works, in 1925, sold Jacques Doucet a 'replica' of his "Piazza d'Italia", painted in 1913.

Among the most well-known forgers are undoubtedly the Dutchman Han Van Meergen, a copier of Vermeer, and Elmyr De Hory, the great forger who specialized in Post-Impressionist paintings. Table 1 shows the most famous forgers in history who were able to produce works 'in the style of', fooling even the most qualified experts.

The high hammer prices at auctions during the mid-eighties of the twentieth century have given way to a market that is more showy and more profitable. One example is the request for fake Van Goghs, for which there was a considerable rise in demand after the exceptional quotations reached at the auction sale of his "Sunflowers" (Christie's, New York) and "Irises" (Sotheby's, London) in 1987.

In this regard, it is interesting to note that the most copied artists in the world are Monet, Renoir, Sisley, Manet, Modigliani, Picasso, Matisse, Gauguin, Cezanne, Klimt and Tamara De Lempicka, while in the Italian market, according to the "Section for forgery and contemporary art" of the *Reparto operativo tutela patrimonio culturale* (Operative Department for the Protection of Cultural Property) of the Carabinieri, they include, Matisse, Magritte, Prampolini, Burri, Fontana, De Chirico, Guttridge, Sironi, Rotella, Migneco, Capogrossi, Gentilini and Boccioni. Trade in fakes is for the most part done on-line.

Table 1. Some of the most famous forgers in history [7]

FORGER	BIOGRAPHICAL NOTES
Icilio Federico Joni, Italy (1866-1946)	Specialized in Renaissance paintings, he produced fakes of lesser-known artists such as Sano Di Pietro and painted new works by more well-known artists. It is a widespread belief he is the author of: • a "Madonna with Child and Angels", presumably by Sano Di Pietro, part of the Cleveland Museum of Art collection (exhibited in 1948); • a "triptych" on display in the Courtauld Institute art gallery; • a "Madonna with Child and Saint Mary Magdalene and Saint Sebastian" attributed to Neroccio di Bartolomeo Landi, part of the Lehman collection in the Metropolitan Museum of Art in New York. In 1936, Joni published a book of memoirs entitled "*Gli affari di un pittore*" ("Affairs of a Painter") in spite of attempts of corruption on the part of many antique dealers who did not want the true provenance of a large number of paintings to be disclosed. Several parts of the English translation were censured for the same reason.
Han Van Meegeren Holland (1889-1947)	The work of this Dutch forger was discovered after the Second World War, when a Vermeer, of which nothing was known, was discovered in the collection of the Nazi leader Hermann Goering, who had purchased it for 256,000 dollars. As a result, Van Meegeren was accused of selling a Dutch national treasure by collaborating with the enemy. Faced with the possibility of the death penalty he confessed to having faked the painting. His fake was so well done that he had to prove his guilt by painting another picture in prison. Van Meegeren's skill by itself, would not have been enough to fool the experts, if he had not had the foresight to procure the materials that were used three hundred years earlier and to avoid using paintbrushes produced in the twentieth century. For his fakes, he reused old canvases from the 1600s with no artistic value from which he carefully scraped off the color. He then carefully inserted dust into the fake he had just finished to produce *craquelure* (the spontaneous network of small cracks typical of old oil paintings). He was also well-acquainted with the Treaty of De Vild regarding the techniques and materials used by Vermeer and made frequent use of the rare pigment ultramarine blue, made from precious lapis lazuli, and oil of lilac.

Elmyr De Hory, Hungary (1905-1976)	A highly skilled forger who, in the course of his life, painted thousands of fake paintings today valued at more than 60 million dollars on the international art market. His paintings, attributed to Picasso, Renoir, Modigliani and Matisse have been sold in the most prestigious art galleries and museums around the world. In 1973, his activity as a forger was publicly disclosed in the documentary film by Orson Welles "F for Fake". Without his spontaneous confession no one would ever have known that some drawings by Matisse were actually his and, at the time, judged by experts to be genuine Matisses from his last period.
Tom Keating, England (1917-1984)	In 1976 thirteen paintings by Samuel Palmer, a famous English artist, inexplicably appeared on the market at the same time. Following the investigation, Tom Keating admitted to faking them, along with over 2,500 other paintings. He confessed that during his twenty-year long illicit career, he had reproduced works attributed to Rembrandt, Degas, Goya, Toulouse-Lautrec, Monet, Van Gogh and others. Keating claimed he had left a clue in each painting to reveal it was not authentic, either by employing modern materials or writing 'this is a fake' on the canvas with lead-based paint, only visible using appropriate diagnostic techniques. Keating is considered one of the greatest forgers to have misled art experts for such a long time, which is precisely why his paintings have increased in value. His "Monet and his Family in their Houseboat" was sold at auction for 32,000 dollars. At the time of his death in 1984, his work was so popular that other forgers started to copy it. Christie's has sold 204 of his works at auction.
Eric Hebborn, England (1934-1996)	A graduate of the Royal Academy of Art in London, Hebborn began to paint fakes after a famous art dealer in London bought a drawing which was the reproduction of a portrait by Augustus John, one of the most famous British artists of the time. It went unnoticed and the drawing was sold as authentic. As a result, he specialized in the sale of antique drawings, founding with a friend, a small company called Pannini Gallery. Here, the lesser drawings were certainly authentic, while more important ones attributed to Stefano Della Bella, Castiglione, Piranesi, Mantegna, Poussin, Van Dyck, Bruegel, were basically fakes, created of course by Hebborn. The business of trading these drawings was carried out with major international dealers and prestigious auction houses. Hebborn said he produced about 1,000 forged drawings by Flemish artists, Peter Paul Rubens, Raphael, Anthony Van Dyck, Nicolas Poussin and the eighteenth century painter Giovanni Battista Tiepolo. The forger wrote two books of memoirs, one of which explained his tricks for aspiring forgers. In 1996 he was killed in mysterious circumstances in Rome.

John Myatt, England (born 1945)	Myatt teamed up with the gallery owner, John Drewe, to fake and create the authentication of works by Chagall, Giacometti, and others. It is considered the most significant art scam of the twentieth century. These pieces were actually inserted in the royal archives, so that scholars could later "discover" them. Although the fraud was discovered along with 60 of the fakes, 140 fakes still remain to be found. They had initially been sold by Drewe to the auction houses, Christie's, Philips and Sotheby's and dealers in London, Paris and New York; they are now probably in private collections and quoted as originals. After serving his prison sentence, Myatt helped track down other forgers.
Wolfgang Beltracchi, Germany (born 1951)	Beltracchi is a forger from the German region of the Rhineland who has faked at least 100 paintings by expressionist artists earning for himself about 30 million euro.
Mark Landis, USA (born 1955)	It is believed Landis has given away more than a 100 works of art, which he himself has faked, to museums in the US. To make these donations, which at the time appeared genuine, he used different identities and disguises without ever receiving money or tax benefits. Landis painted on copies produced after photocopying the original. He then projected it onto a board and painted over it.
Robert Driessen, Netherlands, (born 1959)	Driessen is considered to be one of the greatest art forgers in the world. With a career spanning over thirty years, he has specialized above all in the creation of fake sculptures and paintings, in particular works by the Swiss artist Alberto Giacometti. He has painted about one thousand art works, some of which have been sold at Sotheby's and Christie's. It was in 1987 that he subsequently devoted himself to sculpture, especially reproductions of Giacometti's works. The approximately 1,300 falsified statues have earned him together with his accomplices around 8 million euro.
Shaun Greenhalgh, England (born 1961)	Greenhalgh and his octogenarian parents were convicted of forgery in November 2007. According to the authorities, they have been the protagonists of the most far-reaching organized forgery of all time. The Greenhalghs created works of astonishing diversity, from British sculpture of the twentieth century to an Egyptian statue presumably dating to 1350 BC, fooling even Christie's, Sotheby's and the British Museum. The Greenhalghs were discovered when an expert from the British Museum noted that some Assyrian tablets with sculpted reliefs, allegedly created in Mesopotamia around 700BC contained spelling errors in the cuneiform writing.

4. Reproducing art: legal aspects

To complete the picture, it is equally important, on the issue of art reproduction and in view of the consequent proposal for a research project, to refer to the legal framework that regulates the reproduction of art. It was in England in 1735, that the first copyright law was enacted, which in addition to protecting the author of the "intellectual work" together with the consumer-user, created the divide between what was genuine and of value, and what was not and consequently of no value [8].

With the introduction of this act, forgery soon became a topic of discussion, thus distinguishing it from ordinary imitation. This meant forgers were subject to an actual penalty, whereas previously they had only risked a moral condemnation. In Italy, the various criminal offenses involving the forgery of art works are set down in Law no.1062/1971 and are found again in Art. 178, under "Forgery of Works of Art" (the English is taken from Legislative Decree no.42 of 22 January 2004, *Ministero per I beni e le attività culturali*, Rome, June 2004), in the "Code of the Cultural and Landscape Heritage"[9].

Article 178

1. "The following shall be punishable by imprisonment for a period of three months to four years and with a fine ranging from € 103.00 to € 3,099.00:
   a. whosoever, for purposes of gain, counterfeits, alters or reproduces a work of painting, sculpture or graphic art, or an antique object or an object of historical or archaeological interest;
   b. whosoever, even if he/she did not participate in the counterfeiting, alteration or reproduction, puts on sale, or holds for purposes of sale, or introduces into the territory of the State for such purpose, or in any case puts into circulation, as authentic, counterfeited, altered or reproduced samples of works of painting, sculpture, graphic art or antique objects, or objects of historical or archaeological interest;
   c. whosoever, knowing them to be false, authenticates works or objects, indicated in letters a) and b) which have been counterfeited, altered or reproduced;
   d. whosoever, through other declarations, evaluations, publications, affixation of stamps or labels or by any other means, certifies as authentic or contributes to the certification as such of works or objects indicated in letters a) and b) which have been counterfeited, altered or reproduced, knowing them to be false.

Article 179. Non-punishable cases.

1. The provisions of article 178 shall not apply to whosoever reproduces, holds, puts on sale or otherwise distributes copies of works of painting, sculpture or graphic art, or copies or imitations of antique objects or objects of historical or archaeological interest which are expressly declared to be inauthentic when exhibited or sold, by means of a written annotation on the work or on the object or, when this is not possible because of the nature or size of the copy or imitation, by means of a declaration issued upon exhibition or sale".

Hence, the reproduction of art is manifested in three distinct cases, characterized from the outset by a spirit of "deception":

- in the first case, a product is made that imitates the style of the work's creator;
- in the second case, famous works are reproduced, which are declared to be inauthentic by the "copying" artist;
- finally, there is the willful intent for a work to forcibly enter the circuit of the art market which leads one to believe it is an original, the work of a great master. This last case represents the quintessential of "fake art".

In legal terms, it follows then that to define a work of art as a forgery, there must be evidence of intentional wrongdoing. The issue of art forgeries is connected to that of copies and replicas. But neither the copy nor the replica is made with fraud in mind, whereas the forgery, as already pointed out, is a repetition of the original with the intent to defraud. Until the nineteenth century, moreover, a copy had a conservative purpose, as it was designed to preserve the memory of deteriorating murals.

A replica, however, should be seen as a repetition, by the author, of a work that represents a model or a prototype. The reasons for replicating a painting or a sculpture may be different. The artist repeats a successful theme either because it is the wish of the collector commissioning the work or to improve the prototype-model by making any necessary alterations or because of a defect in the materials used. Furthermore, it is rare that a replica is identical in every way to the original, because it is usual to find, either in the next work or in successive works, fairly consistent variants, also due to the possible intervention of other workers. The value of replicas is quite varied, and is always linked to the quality and the reasons that led to their creation. It may happen that the autograph replica springs from a deepening, a renewal or a decantation of inspiration and consequently acquires value as an original, or in spite of its exterior identity, value as a new work of art, distinct from the first. Conversely, it is possible that an autograph replica or a work that is very similar to the original decreases in value, through the mechanism of the actual process, to the level of a copy.

In addition to copies and replicas, in between the original work and the forgery are other intermediate categories of works.

To better understand the different types of reproduced art works [3] it is useful to look at the terminology adopted in this field:

- **Authentic**: the work of art belongs entirely to the period specified and to the given artist.
- **Original**: the artwork is by a particular artist and possesses all his stylistic features.
- **Replica**: a new edition of the original prototype, made by the artist himself.
- **Copy**: a work executed by a different artist from the recognized author.
- **Attributed to**: this term indicates that the work was produced during the time of the artist in question and that he is the most likely author.
- **Signed by**: this indication is intended to guarantee attribution to the named artist, though the authenticity of the signature has to be verified.
- **School of**: the artist moves within the circle of a specific Master who is cited directly or is his pupil.
- **Follower**: an artist who reveals some stylistic traits attributed to a specific Master.
- **Fake**: this consists of the total substitution of an artifact for speculative purposes.
- **Reproduced**: a digitally produced work[1].

5. How to recognize a fake, in other words, a work that is "not authentic"

According to the art historian Friedrich Winkler: "Nothing is so apt to sharpen one's ability to discern the genuine as the recognition of a forgery". In response to this statement, Eric Hebborn, the notorious forger, mentioned earlier, adds: "And who better than a consummate forger can recognize what is false?": both cases refer to a subjective evaluation [10].

In the national and international world of the art market and auction houses, an evaluation made by experts is in effect a subjective evaluation based on the analysis of historical, stylistic, aesthetic, iconographic aspects and therefore, refers to the visual quality of the artifact which is completed with the acknowledged expertise of the evaluator. The investigation carried out by the auction house experts are summarized in the Condition Report, a data sheet containing information of a qualitative and not quantitative nature.

Hence, the art expert with his personal critical judgment and on the basis of evaluative comparisons between the artistic qualities of the art work in question and its correspondingly hypothetic "authentic" work, decrees its authenticity or inauthenticity by providing the expertise.

Unable to provide adequately comprehensive answers to these problems, the uncertainty of the art market has encouraged forgery to flourish. As a consequence of this situation, a need exists for buyers to be provided with some guarantee of authenticity.

For this, the subjective evaluation should be integrated with an objective evaluation based on the use of appropriate diagnostic and analytical technologies [11], which in respect of the uniqueness and non-renewability of the artifact, should be non-destructive, non-manipulative and non-invasive[2]. Employing these technologies therefore means that no material samples are actually taken from the artifact.

The current problem to be dealt with in matters of forgery, and in general, works that are inauthentic, is precisely that of ascertaining the authenticity or otherwise of a work of art by adopting scientific methods [12].

In this regard, below is the proposal for a research project which aims to define the correct methodological path to follow; it includes, the cognitive phase concerning analyses of an aesthetic, stylistic, iconographic, historical nature and concludes with the technical-experimental phase, which makes use of analytical-diagnostic and computing technologies [13].

The scientific contribution of various experts, each with their respective skills, through discussing and arriving at mutually decided conclusions regarding the subjective and objective evaluation, will provide a result that is as close as possible to the "scientific truth".

6. Research project

6.1 Procedure

The methodological path includes the following phases:

a. Choice of the art work with certificate of authenticity. For this, it is necessary to draw up a complete and accurate identification card comprising information which includes evaluative historical elements (author, period), artistic features (style, iconography, painting technique), morphological characteristics (analysis of surfaces,

stratigraphy), in addition to constitutive characteristics (materials characterization), and evaluation of its conservation state (existing pathologies, degree of deterioration): this represents the "standard reference identifier of the work". This information may be obtained using the analytical-diagnostic methodologies of the Diagnostic Laboratory for Cultural Heritage of the Alma Mater Studiorum University of Bologna (Ravenna). These methodologies enable diverse components to be investigated and are able to achieve a highly detailed characterization of the materials used in producing the artifact. Data is also collected through the use of computing technologies directed toward the acquisition, processing, and storage of information, relating to the above material components of the work (support, preparatory layer, binder, priming of the support, pigments, colors, etc.) employed by a particular artist and commonly used in a particular area and/or in a particular period.

The opportunity of using a work of art with a certificate of authenticity allows an assessment to be made of the feasibility of producing a reliable software framework. By elaborating on the high-resolution digital dataset of the art work, it would then enable the style of a certain artist to be assimilated and identified, distinguishing and determining the different types of "brushstrokes" used (catalogued by size, thickness, angle, direction, etc.).

Comparing and integrating the analytical-diagnostic data with the above data, obtained by the CETMA (*Centro di progettazione, design e tecnologie dei materiali*) experts in Brindisi, Italy, should contribute to providing an additional unequivocal answer to the question of dating and authenticating the work under examination.

b. Development of a new software tool dedicated to archiving, consulting, sharing, analyzing and enriching digital content (both scientific and humanistic) relating to the protection of cultural property, with particular emphasis on integrating the subjective and objective evaluation criteria for attributing and authenticating works of art.

The system itself will organize data structures, implementing precise standards of interoperability into which competences and heterogeneous information from both scientific and humanistic fields will be constantly channeled. An easy to access user-friendly interface must be implemented for the various categories of users, offering the possibility of interacting directly with people and content. To this end, the specific expertise of the researchers at the *Scuola Normale Superiore di Pisa* (a public institution at university level) has been made available.

Relations among users will be managed through messaging services, various social network-based interaction, practicing communities, synchronous virtual workspaces, forums and emailing, in order to ensure maximum interaction and collaboration, thus fostering the development of a virtual community that addresses the specific topic.

The platform should enable cross-reference research at several levels, on the artists, works (stylistic, aesthetic, iconographic, historical, artistic elements), materials, conservation approach, state of degradation, restoration intervention, analytical and diagnostic techniques, molecular structures and pigments. It must also allow for a continuous input of new data by sociologists, historians, archaeologists, semioticians, experts and scientists who are studying a particular work or a particular material.

Within this context, integrated graphics tools (2D/3D) for the analysis and study of the different content stored in the system are essential. As well as favoring the rapid input and display of the new content, these tools aim to simplify understanding and collaboration between users with varying degrees of skills.

User-friendly interfaces must be developed for managing, manipulating and visual-

izing, and for performing theoretical and experimental spectrometric analyses to allow for rapid comparison between the analysis of the material used to produce the work of art and the analysis of the likely sites (quarries or deposits) the artist's raw materials came from. Furthermore, comparisons between the results of computational simulations regarding the deterioration processes of a specific pigment and experimental analyses on the material of a work, can be of valuable assistance in making a full objective evaluation of the authentication of any work of art.

Transparent overlay of non-invasive diagnostic optical techniques should be implemented. This will allow a rapid comparison in the visible to be made, thus enabling investigation into the nature of the pigments used in producing the work together with their identification.

In addition, the system will include an editor and visual display unit for chemical structures, in order to better understand the structure and properties of the molecular composition of the material.

The system shall enable the acquisition, visualization and manipulation of 3-dimensional models from 3D scanners or from modeling software. Using a visual display unit for 3D models, anyone can study the geometry of an object and examine the traces of workmanship produced by chisels or other tools, directly from the virtual representation of the art work.

Finally, to allow the content in the system to be used by different types of devices and applications, the infrastructure should be equipped with web services. In this way, applications, compatible with any physical device, can be developed which will be able to access the system's resources.

c. The same work of art should be available in the form of a "copy" and/or "forgery" and/or "reproduction", in order to apply the previously mentioned analytical-diagnostic and computing technologies, and consequently obtain those results that identify, in this case, the inauthentic work. Further assistance may be provided by investigations relating to the origin of the constitutive materials: an analysis of the material components of an art work can in fact provide information to exclude or confirm any doubts.

As regards inorganic materials, ascertaining provenance is made through the comparison of data by analyzing the materials of the work in question and the data obtained by analyzing the characteristics of the constitutive materials and sampling the likely sites (quarries or deposits) of collection of the raw materials.

d. While it is true that in the case of a "copy" or "forgery" the subjective evaluation of a historical-artistic nature, supplemented by the objective evaluation of an analytical-diagnostic nature provides a clearly unequivocal answer as regards the originality of the work, it is true that in the case of the "reproduced work" there is currently no way of distinguishing it from the "original": through computerization it is possible to create a work that is identical to the original in shape and color, even reproducing its "materiality".

The purpose of this research also addresses this objective: it can serve as a valuable, and in some ways, essential support, to ensure that both "ethics and aesthetics in art" acknowledge their respective conceptual and applicative limits, but in the end are able to find an appropriate meeting point and the necessary synthesis.

6.2 Analytical-diagnostic technologies to be used

After the preliminary historical anamnesis of the work in question, the procedural steps described in the methodological path are made through the use of the following, preferably non-destructive and portable analytical-diagnostic technologies:

- *Analog and digital photographic equipment*
- *Acquisition system in the ultraviolet (UV)*
- *Photographic and reflectographic equipment in the infrared (IR)*
- *Multi-Spectral Imaging System (MUSIS)*
- *Stereoscopic optical microscopes*
- *Optical polarizing microscopes*
- *Videomicroscope for image analysis*
- *Endoscope*
- *Spectrophotometric colorimeter*
- *X-ray fluorescence spectrometer*
- *Thermo-analyzer (thermogravimetric (TGA) and thermodifferential analysers (TDA))*
- *X-ray diffractometer*
- *Scanning Electron Microscope with microanalysis (SEM-EDS)*
- *Fourier transform infrared spectrometer (FT-IR)*
- *Computer technologies, algorithms, methods which aim to carry out a metrically accurate fusion of the data obtained from the above-mentioned instruments.*

These technologies will provide:

- knowledge of the materials, products and techniques used in previous interventions;
- detection of preparatory drawings and *pentimenti*;
- magnification and examination of details in art works, even in areas which are not easily accessible;
- detection and recognition of products resulting from phenomena of alteration degradation;
- qualification and quantification of any sign of chromatic alteration;
- composition of chemical elements constituting the materials;
- thermal behavior of materials and component chemical species;
- qualitative-chemical knowledge of the mineralogical phases;
- morphological characterization.

7. Conclusion

On completion of the research, the combination of analytical-diagnostic results addressing the knowledge of materials and the artistic technique of the work of art, the use of computer technology, directed at the acquisition, processing and storage of the work's material components, together with the development of software that allows the style of a particular artist to be identified, will provide a valuable contribution to understanding the various and complex issues relating to the attribution and authentication of works of art.

Acknowledgements

The assistance given by Andrea Natali, Chiara Matteucci, and Salvatore Andrea Apicella was fundamental in the drafting of this article. Thanks also go to Angela Mari Braida for her significant contribution as linguistic advisor.

Notes

[1] Reproduction using computing involves the use of sophisticated equipment and advanced digital technologies together with the experience of the restorer. This approach was used for the digital reproduction of the painting on canvas "The Wedding at Cana" by Paolo Veronese carried out by Adam Lowe in 2007. The operational phases of the procedure employed were:

- virtual survey of the art work by recording with digital cameras;
- laser survey used to reproduce the unevenness of the surface;
- digital mapping (with hundreds of color samples);
- reproduction of the image with a particular 3D scanner able to detect the stratification of the work;
- reproduction of the work with a "special printer" which enables the data relating to colors, lines and reliefs to be assembled;
- retouching done by hand by developing an atlas of colors using the original pigments;
- the result was a work identical to the original in size, brushwork and material.

[2] Non-invasive analyses referring to cultural heritage are those which, in respecting the structural integrity (non-destructive or para-destructive analyses), do not alter the thermodynamic equilibrium of the system that is, the action does not create any kind of alteration in the physico-chemical state of the system. Non-manipulative analyses are characterized by only one or, however, by very few steps of treatment of the sample.

References

[1] FERRARIS M., 2012, *Arte. Perché certe cose sono opere d'arte?*, Roma, La Repubblica Editore
[2] APPIANO A, 1996, *Capire l'arte*, Roma, Newton Compton
[3] LORUSSO S., MATTEUCCI C., NATALI A., 2010*, Il mercato dell'arte e le case d'asta: valutazione diagnostico-analitica e economico-finanziaria. L'autentico, il falso, il riprodotto nel settore dei beni culturali,* Bologna, Pitagora Editrice
[4] BOCOLA A., 2012, *I criteri generali di stima di una opera d'arte*,
[5] http://www.artexpertise.it/stimaoperadarte.html

[6] LORUSSO S., MATTEUCCI C., NATALI A., BERTOLINO R., TUMIDEI S., 2007, *Diagnostic investigation and historical-stylistic evaluation of oil painting on metal board. Example of "Cristo Crocifisso con due angeli dolenti".* Conservation Science in Cultural Heritage, vol. 7

[7] LORUSSO S., 2008, *Authenticity and Conservation State of Art Works: the Market and Auction Houses & Presentation of the Historical-Technical Journal "Conservation Science in Cultural Heritage",* Conservation Science in Cultural Heritage, vol. 8.

[8] LORUSSO S., 2009, *The Traditional, the Innovative, the Ephemeral: Conception, Realization, Intervention in Contemporary Art*, Conservation Science in Cultural Heritage, vol. 9.

[9] LORUSSO S., BARONE V., 2012, *The objective and subjective evaluation of the work of art: the two languages of one culture*, Editorial, Conservation Science in Cultural Heritage, vol. 12.

[10] LORUSSO S., MATTEUCCI C., NATALI A., APICELLA S., FIORILLO F., 2013, *Diagnostic - analytical study of the painting "Gioconda with columns"* Conservation Science in Cultural Heritage, vol. 13.

[11] LORUSSO S., MATTEUCCI C., NATALI A., APICELLA S., 2013,*Traditional and non-traditional, innovative and ephemeral materials and techniques in today's cultural heritage,* Russian Chemical Bulletin, International Edition, Vol. 62, No. 7, pp. 1671-1681

[12] COMANDO CARABINIERI TUTELA PATRIMONIO CULTURALE, *Presentazione attività operativa 2012,* http://www.beniculturali.it/mibac/multimedia/MiBAC/documents/1366723626535_Presentazione_attivita_operativa_2012.pdf

[13] http://www.cultor.org/falsi/f.html

[14] CROCE M., *Il falso nel mercato dell'arte*

[15] http://www.carabinieri.it/Internet/Editoria/Rassegna+Arma/2007/3/Studi/03_Croce.htm

[16] Codice dei Beni Culturali e del Paesaggio, 2004 (D.L. 42), Ministro per i Beni e le Attività Culturali.

[17] W. BENJAMIN, 1976, *L'arte nell'epoca della sua riproducibilità tecnica*, Einaudi, Torino.

[18] LORUSSO S., SCHIPPA B., 2001, *Le metodologie scientifiche per lo studio dei beni culturali. Diagnosi e valutazione tecnico-economica*, Pitagora Editrice, Bologna.

[19] LORUSSO S., 2011, *Le metodologie scientifiche per la conservazione dei beni culturali: alcuni casi di studio*, XIV Congresso nazionale di Chimica dell'Ambiente e dei Beni Culturali. La chimica nella società sostenibile, Società Chimica Italiana, Rimini, 2nd-5th June.

[20] LORUSSO S., *Traditional and non-traditional, innovative, ephemeral materials and techniques in today's cultural heritage*, International Conference "Current problems of chemical physics" National academy, Yerevan, Armenia, 9th-12th October 2012.

Biographical notes

Salvatore Lorusso is Full Professor in "Chemistry of the Environment and Cultural Heritage" at the Department of Cultural Heritage of the University of Bologna. He founded and is Director of the Master in "Planning and promotion of artistic and cultural events". He founded and is Director of the two book series' "I beni culturali e l'ambiente" (Pitagora Edizioni, Bologna) and "La formazione e la ricerca nel settore dei beni culturali e ambientali" (Mimesis Edizioni, Milano-Udine) and the historical-technical Journal "Conservation Science in Cultural Heritage". He is the author of more than 380 publications in national and international journals and of 22 volumes covering various subjects and sectors, such as commodities, technology and environment, focusing in particular on the field of cultural and environmental heritage. He has been Vice-President and actually Councellor of the "Società Italiana per il Progresso delle Scienze (SIPS)", established in 1839. He is General Director of the Academy of Enogastronomic Culture. He is Foreign Member of Russian Academy of Natural Sciences.

Vincenzo Barone is Full Professor in "Theoretical and Computational Chemistry" at the *Scuola Normale Superiore* of Pisa. Author of more than 650 papers in ISI journals and of several book chapters with more than 35000 citations, an h-factor of 75, and 7 papers with more than 1000 citations each. The most significant scientific contributions include fundamental developments in Density Functional Theory, solvation theory, and computational spectroscopy, together with state-of-the-art applications in materials chemistry, life sciences, nanosciences and cultural heritage. He is fellow of the *Accademia dei Lincei*, of the International Academy of Quantum Molecular Chemistry, of the European Academy of Sciences and of the Royal Society of Chemistry. He received the Pisani medal in 2014 and the Sacconi medal in 2009. He has been President of the Italian Chemical Society (SCI) and of the Chemistry Panel of the National Agency of Research Evaluation (ANVUR), and is a member of the Advisory Boards of *Spectrochimica Acta* A, Open Chemistry, PCCP, Journal of Computational Chemistry and Theoretical Chemistry Accounts. Further details and full reference list are available on the website http://dreams.sns.it.

Lucio Colizzi is an Information Technology engineer. After many years of experience in ICT, robotics, Virtual Reality and data processing and modeling, in 2001 he became the ICT department Director of CETMA. He has co-ordinated important national research programs and in the last ten years has also been coordinator on several projects in the field of development of technologies for cultural heritage. He has obtained many post-graduate qualifications: BPR, Concurrent Engineering and Quality Function Deployment, STEP -ISO 10303, Simple ++, eM-Plant, eM-Planner, Informix Dynamic Server Administration and Performance Tuning, Design For Manufacturing & Assembly, Object Oriented design with UML, Microsoft certifications: C#; ADO.NET; ASP.NET; XML Web services.NET; PROJECT MANAGEMENT (Bocconi University). As a result of his many interests, he has taught "Project Management and Group Dynamics" as Adjunct Professor at the universities of Bologna and Lecce.

Cosimo Damiano Fonseca is an Italian historian, an expert in Norman-Swabian medieval history and history of the Catholic Church; he has been professor at the University of Lecce and the University of Bari; and professor of the history of Christianity at the University of Basilicata where he was rector for twelve years from the time of its founding in 1982 until 1994. He has been vice-president of the Conference of Italian University Rectors and a member of the National University Council (Consiglio Universitario Nazionale - CUN). He has founded and directed several university research institutes. In 1982 he founded, and is currently the director of the International Center for Joachimist Studies for the study of Gioacchino da Fiore's writings. In 1985 he founded the Istituto Internazionale di Studi Federiciani dedicated to the study of the monuments of Frederick II of Swabia in southern Italy. In 1993, in Taranto, he founded the Centro Studi Melitensi which deals with studies on the Knights Hospitaller of the Order of St. John of Jerusalem. He is a member of several scientific academies: Accademia Nazionale dei Lincei, Istituto Lombardo di Scienze e Lettere, Accademia Pontaniana di Napoli and the Accademia di Scienze, Lettere e Arti di Palermo.

He collaborates with the Italian Institute of the Encyclopaedia Treccani, having taken part in the steering committee of the Enciclopedia Federiciana. In 2006, he was the first Italian to be awarded the Fondazione Hohenstaufen Göppingen prize. He is an honorary member of the Sicilian Institute of Byzantine and Neo-Hellenic Studies "Bruno Lavagnini". He has written over 500 scientific publications and has received many national and international awards.