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Project of Electronic Identity of painting

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***Abstract* – Artwork counterfeiting is an historical problem, which has nowadays still ancient solution, not based on innovative technology, due to the intrinsic nature of the artworks themselves. In this paper an innovative system based on smartphone acquisition and mobile application is depicted to verify artwork authenticity based on typical craquelure patterns present in ancient painting. These patterns are unique and can be modified only via a complete and accurate artwork restoration process. This approach is based on like biometry paradigm (analogue fingerprinting) adapted to the painting pattern.**

I. INTRODUCTION

Currently the concept of artwork overcomes the renaissance notion of knowledge and emotion source. Nowadays the “art objects” have also an extra-aesthetic function. In the antiques commerce we can find objects having high ideological meaning. From one side the artwork is considered as a “status symbol” and having one of them can quickly increase the social status of an individual. On the other hand, the artistic object is widely considered as a good economic investment.

For centuries, the artworks have been considered as “prototypes” in which the main and essential aspect was the formal perfection and the iconographic strictness. The usage of the artist’s hand made the artwork unique and difficult to be counterfeited. Only artists from the same school or other high-level artist were able to “reproduce” the artist touch in their artworks. In addition to this, the modern counterfeit of ancient art objects requests not only a high artistic skill, but also the usage of materials and products no more present in the market. On the contrary, the falsification of modern art is technically simple; all the canvas and material are easy to be found and all the colors are available in the market as industrial standard/professional products. In addition to this, the “artist hand” can be easy to be copied.

In this paper, starting from the consolidated electronic passport infrastructure, we have developed a new approach for certifying artworks authenticity. The proposed method is based on artworks intrinsic characteristics, codified in a way like the one used for biometric identification. This solution is combined with a classical certificate of authenticity for ensuring the link between the certificate and the artwork.

The bases of the proposed method lay on the pattern recognition analysis of artworks and on digital reconstruction techniques, even more and more frequently used in the cultural heritage field [1-7]. Furthermore, the paper also proposes a smartphone application approach.

II. AUTHENTICATION PROCESS FOR ARTWORKS

In the art community an artwork authenticity is decided by well-recognized experts, on a pure subjective evaluation: considerations based on the analysis of historical, cultural, stylistic, aesthetic, iconographic elements, such as on simple visual concepts increased by evaluator recognized competence. In this way, the art expert, with his proper judgment and conforms to comparisons between the under-evaluation artwork’ artistic qualities and a well-known authentic corresponding, autonomously decides if it is authentic or fake and releases the related “expertise” (i.e. Certificate of Authenticity – CA).

Unfortunately, this expertise can be easily exchanged between two artworks, associating to a copy the CA of an authentic masterpiece. In particular, the seller, with the aim of certifying the originality of more than a single artwork, can associate the same CA (sometimes produced by himself) to more than one single artwork. In this way the buyer could have an original certificate of authenticity associated with a fake painting [8].

Art objects maintained inside museum are normally catalogued, by means of photo and related serial number. This couple uniquely identifies the object and can be considered like fingerprints for people. This “object fingerprints” can be easily inserted in modern databases for a quick verification and a simple modification of the related information, such as historical data about the object or the author. Unfortunately, the catalogue serial number can also be easily changed from an artwork to another one, both for a mistake or a fraudulent intent.

In case of private collections or artworks produced by living artists, the only source of authenticity is the related expertise (CA). Unfortunately, there is not any regulation on the content of the CA and the people authorized to produce one. All these considerations, with the addition of the relevant easiness to exchange CA among different artworks, lead to propose alternative to be added at the classic CA for authenticating artworks, in particular (but not exclusively) for modern art.

III. UNIQUE IDENTIFICATION SCHEMA

Methods for uniquely identifying objects cover an increasing importance in the international art market. They could have an enormous impact on illegal artwork commerce, certifying the origin and authenticity of any art object. A good starting point for founding a proper identification schema could be the one well defined in the biometric authentication/identification process. It is based on the creation of a dedicated template starting from images of a person physical (or behavioral but is not the case of interest of this study) characteristic, such as fingerprint, iris, DNA. This template is then recorded inside identification document and used for authorizing access to limited areas or for uniquely identifying a person (e.g. electronic passport) [9].
A similar process can be also envisaged for artworks and, in general, for inanimate objects. It is called Hylemetry, in analogy with Biometry for human being [10-13]. In theory, every random and irreproducible characteristic could be used in Hylemetric identification [14-17]. Hylemetry, using proper and unique physical characteristic extracted from the artwork, can allow to easily verify in any moment the authenticity of an object.

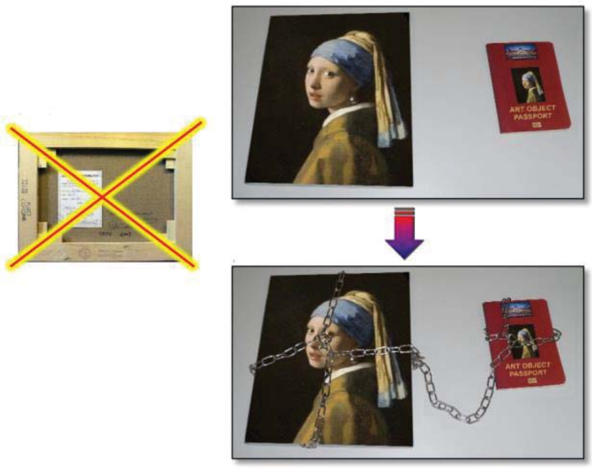

Fig. 1. The Hylemetric identification process allows to substitute the classic and unsecure CA with a modern paper or electronic artwork passport, indissolubly connected with the artwork itself.

IV. HYLEMETRIC AUTHENTICATION PROCESS

Hylemetric authentication is possible if the artwork presents some unique and not cloneable physical characteristic. When this characteristic is identified, it is possible acquiring the related pattern and creating a dedicated template that can be used as authentication template for the object. This process is identical to the biometric one. So, first step is to find a physical characteristic among the possible set of the object, then can be considered stable and not cloneable. Physical characteristics that can be used for identifying objects are manifold. Depending from the artwork type it must be chosen the most appropriate one, both from a simplicity of acquisition and stability during time. For better understand of these concepts considering the craquelure present on the surface of an oil painting (see Figure 2).

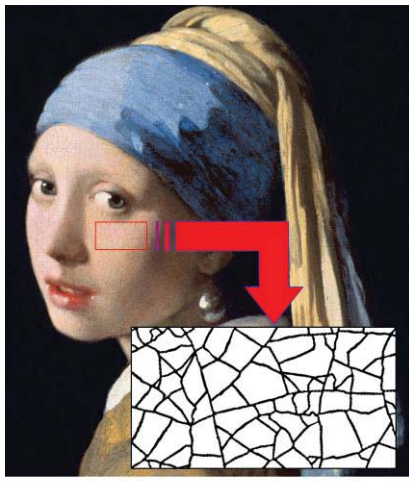

Fig. 2. Craquelure present on Vermeer painted Girl with a Pearl Earring.

Craquelure is apparent in all older pictures and influences their appearance to a greater or lesser extent. The network of fine cracks is dependent on the materials used for painting, the painting technique of the artist, the atmospheric conditions the painting has been exposed to, and the way in which it has been treated. Any craquelure generation process creates a different and unique pattern. It can be considered as the oil painting fingerprint; it is unique, stable and unclonable [18-20].
Indeed, craquelure analysis is traditionally used for verifying painting authenticity [21].
The craquelure peculiarity is that it can change during time [22, 23], but the original pattern remains invariant; only some new cracks will be added to it, but it is always possible to identify the original one [24, 25]. In Figure 3 the temporal evolution of a craquelure pattern is shown.

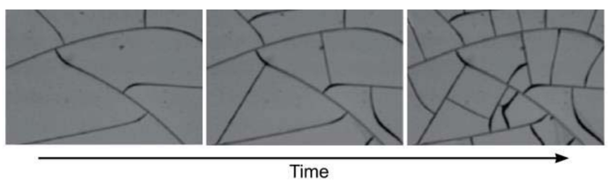

Fig. 3. Time evolution for a craquelure.

Observing Figure 3, it is evident as the original pattern remain invariant and the new cracks adding information without changing the information previously present. Also, in this case the fingerprint similitude is still valid: during time it is possible having some scars that alter the fingerprint original pattern, but the minutiae distribution

remains the same and it is always possible to extract it. Obviously, as for fingerprint, the authentication process will be opportunely tuned using appropriate thresholds, for avoiding false negative due to time evolution.
Obviously, restoration processes, if poorly executed, can modifying the craquelure pattern. It is good practice that, after any restoration, a new pattern is extracted for an artwork electronic passport update.
The craquelure pattern can be constructed using a set of descriptors, like the fingerprint minutiae used in biometry. The descriptive framework is based up on the following features [18]:

1) Predominant direction and orientation of cracks.
    a. NO DIRECTION or DIRECTION; isotropy or anisotropy?
    b. If anisotropic, then PARALLEL or PERPENDICULAR to grain?
2) Changes in direction of cracks.
    a. Locally - SMOOTH or JAGGED.
    b. Globally - STRAIGHT or CURVED.
3) Relationship between crack directions.
    a. paint islands - SQUARE or NOT SQUARE: is there an orthogonal relationship?
4) Distance between cracks
    a. spatial frequency - are the paint islands SMALL or LARGE?
5) Thickness of cracks
    a. are all cracks of UNIFORM thickness or are SECONDARY cracks present?
6) Junctions or terminations of cracks
    a. is crack network CONNECTED or BROKEN?
7) Organization of racks
    a. is crack network ORDERED or RANDOM?

Only a part of them are normally necessary for uniquely describing a painting and creating a robust authentication template. The information inside the RFId has also to indicate which descriptors have to be used.
Many craquelure detection algorithms have been designed [26-31].

V. IDENTIFICATION PROCESS

For explaining the proposed process, taking into consideration a painting. It is under expertise evaluation for producing the certificate of authenticity. This certificate could be glued behind the painting itself. Instead of having a simple paper certificate, we can consider gluing behind the painting something like an electronic passport: a Certificate of Authenticity (CA) having a Radio Frequency IDentification (RFID) on it, which is used to maintain an encrypted version of the template generate from the craquelure pattern and all the necessary information for recreating the template during the authentication phase.

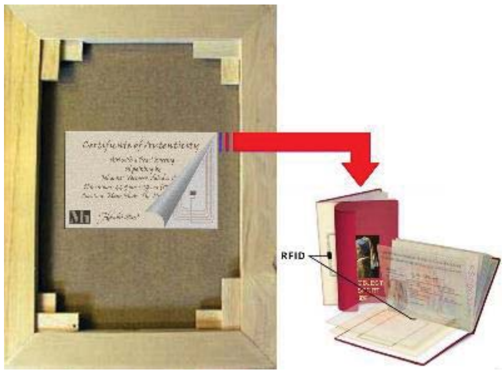

Fig. 4. Painting with the electronic password like CA.

VI. VERIFICATION PHASE

In the following the verification phase is described.
Using a smartphone able to read RFID, it is possible retrieving the authentication data inserted in it.
A connection with a Certification Authority database is established. From the RFID itis possible to extract the encrypted template and the necessary information for reconstructing it. The smartphone software will be able to guide the verifier recognizing painting canvas and allowing using Augmented Reality to acquire the correct portion of it. Then the system calculates the Hylemetric template, using the information on the used craquelure descriptors and applying any necessary geometrical correction necessary due to manual acquisition; in fact, it is possible having crop, scale and rotating errors, that will be automatically corrected using appropriate algorithms. The extracted template is decrypted using the public key associated with the CA author. The two templates are compared each other using a likelihood threshold. The Hylemetric authentication/verification procedure, if correctly applied, grants the unicity of the artwork, and certifies the correctness of the certifier [32].
The schema reported in Figure 5 shows an approach based on a remote DataBase.
The user, by means of the proposed app, can see:

- Painting image, for a first visual verification that the CA is related to that paint;
- Painting and author information;
- Verification data, such as area to be acquired, which will be passed to the app for guiding the verifier using augmented reality;
- Original registered template, encrypted with certifier private key;
- List of the used descriptor for creating the template;
- Associate public key.

The verifier will acquire the paint portion, guided by the app: this image is reported in Fig. 5 as IS or Image Scanned. The system will apply any necessary geometrical correction (as described before), obtaining the Image retrieved (IR). From IR the app can extract a template, using the craquelure pattern and the descriptor extracted from the database.

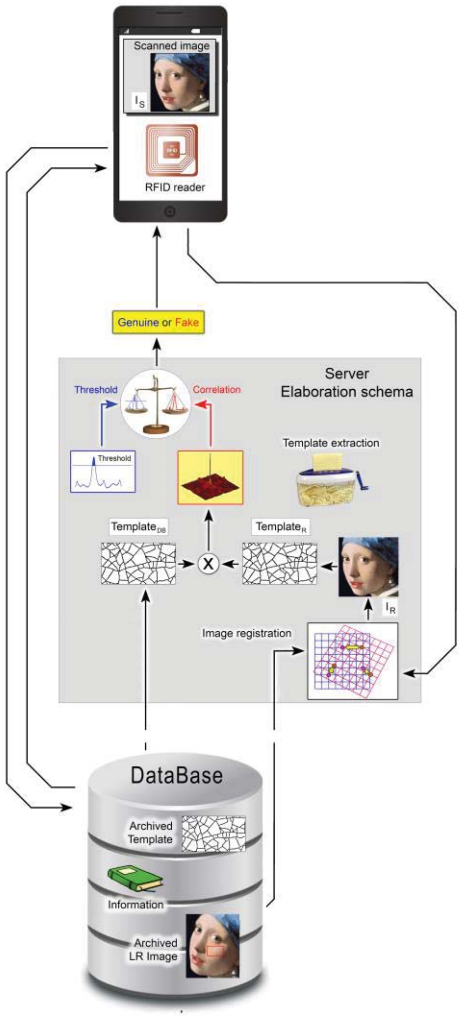

Fig. 5. The application of Hylemetric procedure allows to overcame the usage of classic CA.

The two templates are correlated using a Phase Only Correlation approach. The result is faced with a likelihood threshold. At this point the system can decide if the paint is original, such as if the paint is associated to the reported data in the database and the CA glued on the back. Due to the usage of a smartphone application, the proposed POC is based on Hartley transformation [33-35]. This choice allows to use a fully real correlation function, which is fastest than a classical real and imaginary function such as Fourier one, reducing computational request on the selected smartphone.

VII. CONCLUSIONS

In this paper it is proposed an innovative way to certify and verify authenticity for artworks in general and painting. The solution uses a biometric-like approach, called Hylemetry, based on a physical unique characteristic retrievable from an old painting: craquelure. Using the craquelure pattern, it is possible creating a unique template to be used for certifying the authenticity by a certified expert. The proposed infrastructure implements, as for the classic passports, allows the replacement of the paper document (in the case of works of art the certificate of authenticity -CA) with much more complicated system to be falsified.

Obviously, the suggested method can be easily adapted to different kind of artworks or different kind of physical characteristic to be filled in the Hylemetric process. Examples of usable Hylemetric characteristics are: Surface Microtopography [36,37]; Raman mapping [38]; Elemental maps with X-Ray Fluorescence (XRF) [39].

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