

Project no. 022453

FING-ART-PRINT

Fingerprinting Art and Cultural Heritage - *In Situ* 3D Non-Contact Microscale Documentation
and Identification of Paintings and Polychrome Objects

Specific Targeted Research Project

Policy-oriented research: Priority 8.1.B.3.6 - The protection of cultural heritage and
associated conservation strategies

FING-ART-PRINT Final Report

Publishable Final Activity Report

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FING-ART-PRINT Publishable Final Activity Report

1. Introduction

The increased movement of cultural heritage brings with it major concerns for conservators and curators. Problems associated with loans and special exhibitions of objects include not only the well-known dangers of (irreparable) damage in transport or due to poor exhibition conditions, but also increasing exposure of objects to the possibility of loss or theft. The general public is aware of spectacular thefts such as the armed robbery of Edvard Munch's "The Scream" from the Munch Museum in Oslo, Norway, in October 2005, or the break-in at the Van Gogh Museum in Amsterdam in December 2002. In addition, thousands of lesser known but, from a cultural and historical standpoint, equally valuable objects are waiting to be found, listed, for example, on the Art Loss Register, the ICOM Red List, and/or Interpol's "Stolen Works of Art" CD-ROM. However, this is just the tip of the iceberg of a much more serious problem, only now getting public attention due to the controversy surrounding the source of objects found, among others, in the J. Paul Getty collection or the Metropolitan Museum of Art, New York City. The illicit trafficking of stolen objects has been a problem for centuries, and continues to be a major problem to this day for archaeological sites and museums which lie unprotected in war zones such as in Afghanistan and Iraq. The greed of unscrupulous collectors and looters alike has resulted in the removal, damage, and/or loss of countless numbers of objects, both in the physical and economic, as well as in historical context.

A key problem in fighting the illegal trafficking of objects, as well as the tracking and tracing of objects in transport and on loan is their irrefutable identification. Museum objects are generally identified using some sort of cataloguing system. The objects may be (digitally) photographed, and then marked using a sticker, perhaps with a barcode, or a marker. This information is then entered into a paper or modern software catalogue/database along with other descriptive and historic information, condition reports, etc. Besides the fact that stickers and markers have the disadvantage of reacting with the objects they are applied to, they have the additional disadvantage that they can be removed and/or forged.

In the field, in particular, at archaeological sites in third world countries, the identification of objects can be far more difficult. Due to time constraints and/or the sheer number of objects, if an object is documented at all, it is often with a rudimentary sketch and/or photograph, and perhaps a label. At a dig in progress, many objects will lie undiscovered and thus undocumented due to similar time constraints, and thus easy prey for thieves at an unsecured site. In any case, when objects come through a customs checkpoint, much depends on the customs officer's knowledge and expertise to recognise an object for what it is, whether stolen or not. Given the number and wide variety of objects in circulation, this is a virtually impossible task. There is thus a need for a method for identifying objects quickly and uniquely, without doubt.

2. Objectives

This method has been developed in the project FING-ART-PRINT, conducted within the Sixth Framework programme of the European Commission, Policy-oriented research: Priority 8.1.B.3.6 - The protection of cultural heritage and associated conservation strategies. The FING-ART-PRINT technique involves taking a unique "fingerprint" of an object without coming in contact with the object. This fingerprint consists of the measurement of the roughness and reflectance spectra (colour) of an object at some position on the object, for example,

a square centimetre, selected by the owner. The fingerprint is stored in a digital file containing a combination of the following information for a selected area(s) of the surface of an object:

- three dimensional (3D) roughness/texture information on a (sub)micron scale (the roughness fingerprint)
- high resolution spectral information about pigments and dyes used (spectral fingerprint)
- a high resolution 3D accurate colour digital image of the selected area(s).

The project had the following four main objectives/work packages (WP):

- WP 1 - develop individual roughness and spectral reflectance measurement equipment for the specific application of taking fingerprints
- WP 2 - develop a user friendly version of all required software for (re)taking fingerprints for integration into the FING-ART-PRINT system as well as for post-processing
- WP 3 - integrate the hardware and software developed in WP's 1-2 into a complete, compact FING-ART-PRINT system for finger-printing objects
- WP 4 - verify that the FING-ART-PRINT can take a legitimate fingerprint of an object of art or cultural heritage, and that this fingerprint is a unique and lasting characteristic of an object.

3. Results

Prototype FING-ART-PRINT system

The FING-ART-PRINT project was successfully completed, and virtually all objectives were accomplished. A user-friendly prototype apparatus for taking fingerprints was developed and optimised within the project, with the help of end users from museums and other cultural heritage institutes. The final apparatus, as shown in Fig. 1, consisted of a white light confocal profilometer (partner NanoFocus AG) for measuring roughness, mounted on a robot arm, which itself is mounted on a solid granite plate for stability. This allows roughness fingerprints to be taken in almost any orientation on and of an object. A webcam mounted on the robot itself allows the user to document the position of the fingerprint.

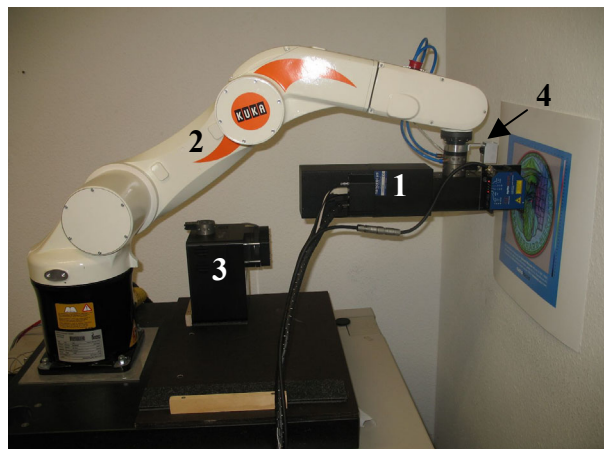


Figure 1 - Prototype FING-ART-PRINT system with NanoFocus confocal profilometer (1) integrated into robot system (2), free-standing ELDIM multi-spectral camera (3) and webcam (4) for documenting the position of fingerprints.

For the FING-ART-PRINT system, a commercial confocal microscope, μ Surf®, from NanoFocus was adapted for use for taking fingerprints, and for operation on a flexible robot system. The profilometer can take roughness fingerprints of up to one square centimetre, at a lateral and depth resolution of less than one micrometer. It should be noted that the theoretical depth resolution for the profilometer is on the order of nanometers, but this was not considered necessary for the fingerprints. NanoFocus optimised many aspects of this technology for adapting to the robot system, as well as to increase the stability of the measurements. This included adapting accompanying software package, μ Soft®, for use with the FING-ART-PRINT user interface. ICN and OADC conducted tests using both model specimens and objects (case studies) to help optimise the operation of the system.

The multi-spectral camera for obtaining spectral fingerprints was a new development by partner ELDIM. ELDIM originally planned to develop an innovative spectral imager based on Fourier transform spectrometry. However, this was not successful due to mechanical stability problems. The multi-spectral camera, MSColor32 was thus developed based on band pass filter technology, and makes use of 31 band pass filters across the visible light spectrum. The camera can be used to image areas down to several square millimetres. For fingerprinting, it takes spectral information for every single pixel of the image, at a spatial resolution of several micrometers. Dedicated software for Active X control was developed for integration into the FING-ART-PRINT user interfaces. UPMC conducted work to validate the reflectance spectra taken by the camera.

The integration of the hardware was conducted by NanoFocus. The robot system was specially constructed for the prototype, and includes a number of special parts of a Kuka-robot-system to combine them to a special positioning machine. Both the confocal profilometer and the multi-spectral camera were reduced in weight to under 5 kg to allow the robot to operate at maximum performance capacity. A sensor changing system was developed so that the robot could take measurements with one instrument, and then exchange it for the other. A confocal stitching procedure was implemented into the robot control software to allow the confocal profilometer to take fingerprints of larger areas than the profilometer can take at one time. The multi-spectral camera could not be integrated into the FING-ART-PRINT prototype but can operate stand-alone.

The operation of the FING-ART-PRINT system was controlled via a user interface software created by UOS. This software helps non-technical users control the movement of the robot, and to take measurements in a user-friendly manner. NanoFocus optimized its μ Soft® software for use in the interface. ICN and OADC provided assistance to ensure this user-friendliness, and the comments of conservators who attended FING-ART-PRINT workshops were also quite useful in this respect. However, a hidden expert interface is available which allows technical support personnel to make changes if required.

An important feature of the user interface is to assist users in "refingerprinting" an object, that is finding the original position of the fingerprint so that a new fingerprint can be made, or that an old fingerprint can be checked. UOS developed fast code to correlate previous images of the object from the webcam, with current live images. This helps the user steer the robot to its original position and orientation with respect to the object.

In summary, the FING-ART-PRINT system is compact and allows fast, easy measurements of object surfaces *in situ*. It is user-friendly, so that a non-technical person from the museum

world such as an art historian, collection manager, or conservator can easily use it for routine measurements in real time to allow analyses in front of the work of art. The system is transportable to any location (for example, the storage room or exposition room of a museum), and can be easily assembled and disassembled. Routine fingerprint measurements which can be carried out in reasonable time (several minutes per object) and without any special room conditions. The only crucial condition is the sensitivity to vibrations which has to be taken into account.

Fingerprinting experience

During the FING-ART-PRINT project, it was clearly demonstrated that unique fingerprints (roughness) can be taken from almost all types of objects and materials to be found in cultural heritage. This technique was successfully demonstrated to over 70 international conservators and other cultural heritage personnel using the FING-ART-PRINT prototype during two workshops. Three sets of case studies were also carried out over the duration of the project. Nine museums, one art gallery, two cultural heritage institutes with their own collections (ICN and OADC), several private conservators, and three law enforcement units participated, providing over 35 objects for roughness fingerprint measurements. These included paintings with and without varnish, books and lithographs, cast metal objects, corroded metal objects, archaeological and historic ceramics, with and without glazes, and wood.

An example of the uniqueness of the fingerprints can be seen in Figs. 2 and 3. Fig. 2 compares two dumbbell shaped objects from a sculpture by Tom Claasens (Galerij Fons Welters; Kröller-Müller Museum). Fingerprints were taken at the same position on both dumbbells, at the end of a nick visible by the naked eye in the shaft, see the small spots of white line shining from the objective lens approximately at the center of the shaft (marked by arrows) in Fig. 2ab. The roughness measurements are shown as a 3D false colour image where red is high and blue is low, the entire range between red and blue being about 160 μm (0.16 mm). The main nick can be seen in both roughness fingerprints (rectangle in Fig. 2 cd). However, the nick seems to be further extended in the dumbbell shown in Figs. 2 bd (see oval). This could be a result of wear of the casting mould. In any case, the two dumbbells cast from the same mould can be uniquely identified with a roughness measurement alone.

Fig. 3 shows a similar comparison for two maps from two of the same book printed using the same printing press. Generally, it could be assumed that ink would soak into the paper it was printed on. However, in this case, the "5" on the map to the left (enlargement in Fig. 3c) is identifiable in light yellow in the false colour roughness data, encircled in Fig. 3a, while the "5" in the map to the right is not visible, see Figs. 3 bd.

An example of the relocation of a fingerprint on a reproduction of a Van Gogh painting can be seen in Fig. 4. It should be noted that in this example, the fingerprint was (easily) relocated by hand. The FING-ART-PRINT user interface system will further ease this process.

Based on the results of the workshops and case studies, as well as other considerations, a protocol for taking the fingerprint was developed. The two main issues considered in the development of this methodology were: 1) the condition of the object when it is fingerprinted, and 2) the actual workflow in the fingerprinting procedure. The condition of the object when it is fingerprinted will determine to a great extent how unique and durable the fingerprint will be. The methodology will serve as the basis for international standards for the use of finger-

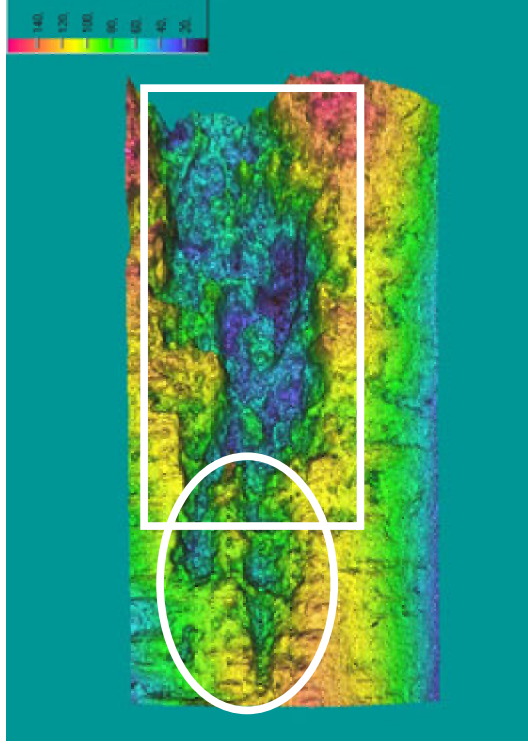
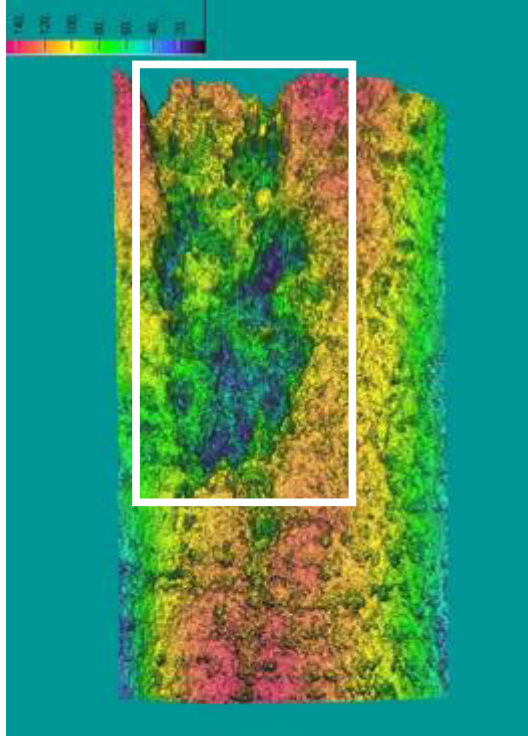
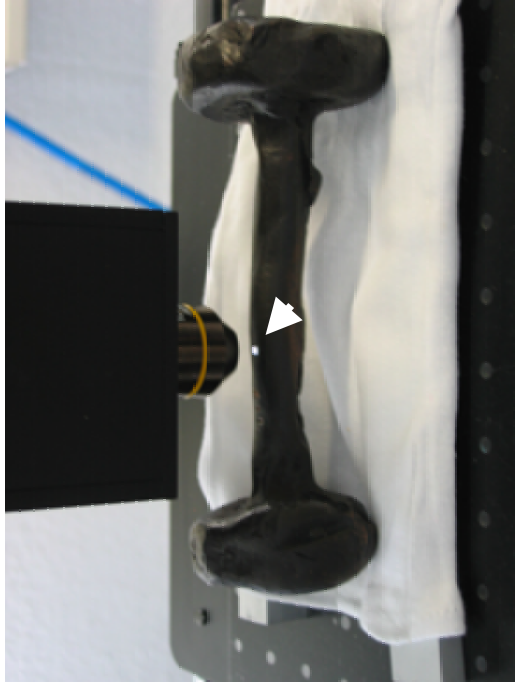


Figure 2 - Comparison of roughness fingerprints taken from two dumbbell shaped objects cast using the same mould (see text for explanation).

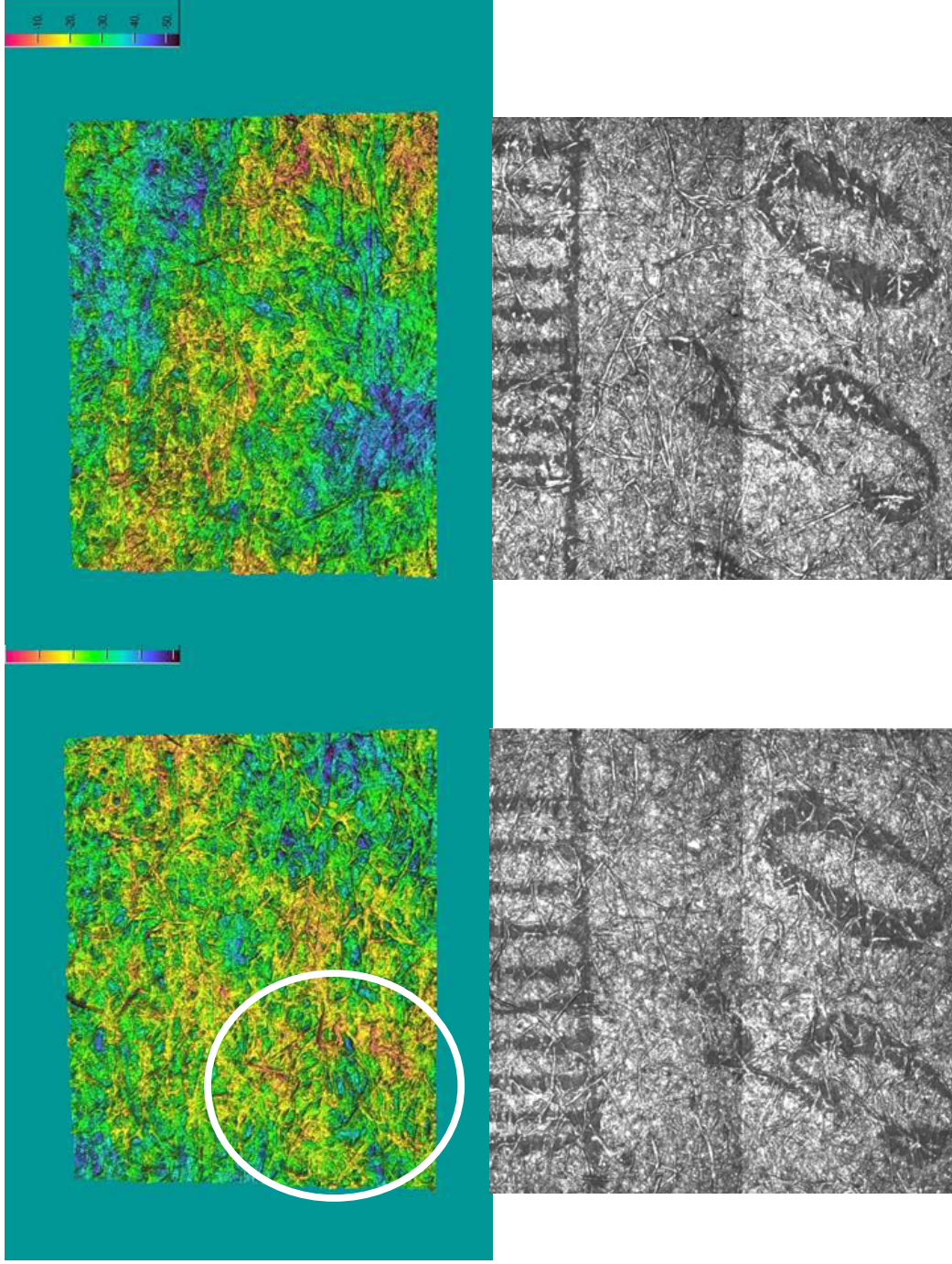


Figure 3 - Comparison of roughness fingerprints taken from two maps (the number 5) printed using the same printing press (see text for explanation)

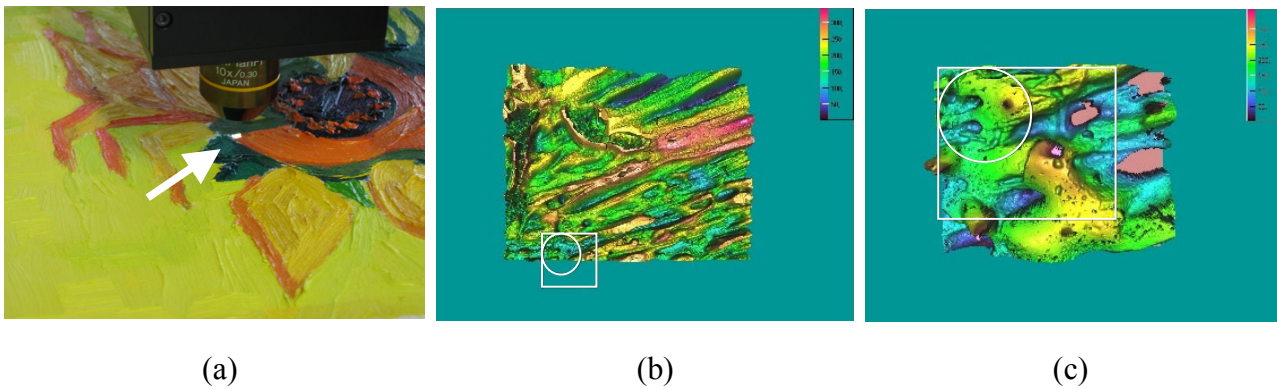


Figure 4 - Roughness fingerprints taken from a test panel reproducing Van Gogh's painting technique on linen (object courtesy Van Gogh Museum, Amsterdam).
 a) Location of fingerprint shown by the spot of light (arrow).
 b) False colour topographic map (8 x 8 mm). Height scale is 350 μm , where light colours (red/yellow) are higher and darker colours (blue/green) are deeper. Match with (c) is indicated by the square and circle.
 c) False colour topographic map taken by the FING-ART-PRINT robot (1.6 x 1.6 mm). Match with (b) indicated by the square and circle.

prints for the identification of objects, for tracking and tracing, and for combating the illegal trafficking of cultural heritage.

Durability of fingerprints

ICN and OADC conducted a number of studies to determine the durability of fingerprints. Model specimens as well as the case study objects were reprinted a number of times, after aging in the case of specimens, and over the course of the project in the case of the objects. Roughness fingerprints were relocated in almost all cases, and underwent little change over the duration of the project. Most of the spectral testing was performed using an goniospectrophotometer developed by UPMC, because the ELDIM camera was not yet operational. During aging, the spectral fingerprint changes as to be expected. For the short aging times, this showed itself as darkening, thus the form of the spectra did not change. Work must continue to determine the validity of spectral fingerprints if there are also chemical changes which change the form of the spectra.

4. Applications

FING-ART-PRINT is expected to have an enormous impact on the identification and protection of moveable cultural heritage. The system is compact and allow fast, easy measurements of object surfaces *in situ*. It will give curators a non-contact method for "marking", identifying, and tracing works of art, precluding the need for stickers or markers. It will give conservation scientists the possibility for studying changes of the surfaces of artworks due to cleaning and other surface treatments on the object itself, as well as the effects of climate and aging on the condition of objects. Finally, the instrument is user-friendly, so that a non-technical person from the museum world such as an art historian, collection manager, or con-

servator can easily use it and evaluate the results. The results should be recorded in real time to allow analyses in front of the work of art in the presence of curators, conservators, etc.

Besides use for existing collections around the world, FING-ART-PRINT will have an enormous impact in fighting illegal trafficking and protecting objects from theft and commercial resale. It is difficult to put a figure on how many objects are endangered and/or already stolen or missing, this in light of events in Afghanistan and Iraq, but many other third world countries where archaeological finds are continuously being plundered. A CD put out by Interpol for use by national and international law enforcement agencies lists over 26,000 objects (see www.interpol.int/Public/WorkOfArt/woafaq.asp), but this is certainly only the tip of the iceberg. Recent thefts of Van Gogh and Munch paintings are EUR million crimes. A number of European initiatives, directives, and regulations have been developed to improve the traceability of objects of cultural heritage, and make it much more difficult for stolen objects to be sold. However, monitoring and tracing of objects has not been possible up to now because of the lack of a reliable and standard non-contact method for identifying and documenting such objects. The development of international databases for endangered or stolen art has actually already been started by, for example, the Getty Information Institute with international governments and other bodies such as Interpol (Object ID), and the International Congress of Museums ICOM (Red List). However, many museum archiving systems are not standardised, so that linking them, with or without fingerprints, is difficult.

FING-ART-PRINT makes innovative use of advanced technologies developed for "normal" industrial use in order to provide fingerprint records of objects of art and cultural heritage, this without any physical contact with the object, and non-destructively. The uniqueness of the fingerprints will allow the improvement of international databases such as those mentioned above for such objects. This is a particularly important development which needs to be performed on a European level, given the open borders, the ease of transport between countries, and the desire for objects on loan, and/or complete travelling exhibitions. In fact, the FING-ART-PRINT is expected to provide a significant impetus in the fight against illegal trafficking. ICN, NanoFocus, and OADC have begun with the organisation of a European, and eventually, an international network to provide the basis for this important activity. This not only includes the fingerprinting process, but the development of a uniform legal framework for controlling the export, import, and sale of objects of cultural heritage.

As an extension to the identification task to be addressed by FING-ART-PRINT, the system will also have a significant impact on the analysis and detection of frauds. It will allow museums and law enforcement authorities to clearly mark and identify objects which are already known to be authentic. In the case of the loss and recovery of an object, a fingerprint of the object can be taken and compared with the above-mentioned databases containing objects which have been fingerprinted, in exactly the same manner as law enforcement officers use fingerprints, DNA, or dental records to identify missing persons, criminals, or potential personnel security problems.

5. Consortium

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For more information about the project, contact the project coordinator at the address above, or visit the FING-ART-PRINT website at www.fingartprint.org .