Non-contact method for the documentation, evaluation and monitoring of conservation treatments for icons.

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Figure1
"St Georgios from Ioannina" painted on wood, dimensions 31 x 23 x 1.5 cm, folk style of the 19th century.

Introduction

Icons continue to serve their purpose as liturgical objects for worship, which are preserved in churches or in heirloom private collections. However, as important works of art, icons are progressively gaining greater appreciation within the artistic community. A consequence of this increased interest for iconographic artworks is an increase in the movement of icons on loans for special exhibitions.

This fact introduces additional dangers to the preservation of icons, including possible damage in transport or due to poor exhibition conditions increased exposure of objects to the possibility of loss, theft or illegal trafficking.

Consequent necessity for the protection of icons is their systematic substantial archiving, which in many cases is lacking and the particular interest for the development of new tools and methods for identifying, tracing and documenting through the application of well diffused analytical techniques or innovative technologies.

The continuous use of icons as liturgical objects has also important consequences in terms of aging. This will be much more significant than that for objects on display in the protected and controlled climatic conditions of a museum or gallery. In the particular case of the icons used in churches, regular cleaning and conservation will be required due to worship practices such as the lighting of candles or incense, and the veneration/touching of objects. A major concern for conservators of such objects is how to preserve the integrity and reproduce the original appearance of the icon after such periodic removal of dirt and renewal of varnish. A complete characterisation of the physical and chemical structure of (the surface of) the object is thus of enormous importance for selecting proper conservation treatments and methodologies.

In principle, the appearance of an object depends on the interaction of light with its surface. This interaction includes selective absorption, transmission and scattering of light through the layered structure which can consist of semi-transparent layers such as yellowed varnishes and/or glazes on top of opaque paints. The chemical composition of the pigments and colouring compounds, the surface topography, any deposits, and/or damage or chemical changes occurring with time also affect the optical properties of the overall surface. Current characterisation and documentation techniques are not as yet sufficient on accurately characterise and document such surface properties.

In situ roughness measurements using confocal white light profilometry have recently been used to document changes in the three dimensional structure of paintings after cleaning (Wei, 2005). It has been shown that details of an artist's brushstroke can be identified down to micrometer (μm), that is, pigment grain levels. On the other hand, spectral diffuse reflectance measurements in the visible light range provide unequivocal information on the pigments of the paint surface (Sister Daniilia, 1999; Sotiropoulou 2003).

A novel method is being developed within a European project, FING-ART-PRINT[1], for the non-contact high-resolution "fingerprinting" of objects of art and cultural heritage (Wei, 2006). The fingerprint consists of roughness data (topography) and reflectance spectra in the visible range (colour) of one or more selected proprietary areas (for example, 1 cm^2) of a painted surface, measured on a micrometer scale. At that scale, such information is unique to the painted object, and is, in fact, the artist's technical "signature".

The FING-ART-PRINT methodology not only provides a long sought after non-contact method for identifying and documenting valuable painted objects of art and cultural heritage. It is proposed in this communication, that the method can also be used for the non contact documentation and evaluation of conservation treatments on icons.

In this communication, results are reported for the fingerprinting of the icon, "St Georgios from Ioannina", Figure 1, owned by the Sacred Convent of the Annunciation, Ormylia, Greece. The icon is painted on wood with egg tempera paint in the folk style of the 19th century, with dimensions of 31 x 23 x 1.5 cm.

In addition, results are reported from systematic roughness and colour measurements of model paint/varnish layers similar to those found on icon panels (see figure 2). These measurements were carried out with the objective of defining the appropriate experimental conditions (parameters) for studying the impact of the varnish and the effect of aging or cleaning on the surface properties of the paint layers. The results show that the FING-ART-PRINT system can be used as a tool for the examination, documentation or evaluation of conservation treatments such as cleaning and revarnishing.

Experimental

The equipment being developed for taking fingerprints of objects will consist of a (trans)portable combination of a confocal white light profilometer and an imaging spectral interferometer. The confocal white light profilometer is a modern, commercially available instrument designed and manufactured by the FING-ART-PRINT partner, NanoFocus AG, Oberhausen, Germany. The imaging spectral interferometer is actually under development by the FING-ART-PRINT partner ELDIM S.A., Herouville St. Clair (Caen), France. Both instruments will be mounted on a robot arm, which will have to be virtually vibration-free to enable the user to obtain the high spatial and depth resolution required for the roughness measurements. Six degrees of freedom of motion will allow the sensing head to be positioned at almost any area selected by the user on an object. User-friendly software will be written by the University of Southampton with the aim of allowing non-technical museum personnel to operate the fingerprinting procedure. A background software interface will allow technical staff to adjust measurement parameters as necessary. Further features of the software will include semi-automatic relocation and matching of fingerprints which are already available in databases.

In order to support the development of the FING-ART-PRINT equipment and methodology, initial measurements and case studies are being conducted. Relevant surface texture and colour properties are being defined for use as fingerprints.

Roughness measurements were taken using a NanoFocus µSurf ® confocal white light profilometer. The profilometer works essentially on the principle of focussing an object in a light microscope. When an object is focussed the objective lens is moved up and down. If the microscope follows the roughness of a surface, the lens must automatically move up or down to keep it in focus. By measuring the vertical motion of the lens, a topographic profile is obtained. For more details on the principles of confocal white light profilometry, see (Wei, 2005).

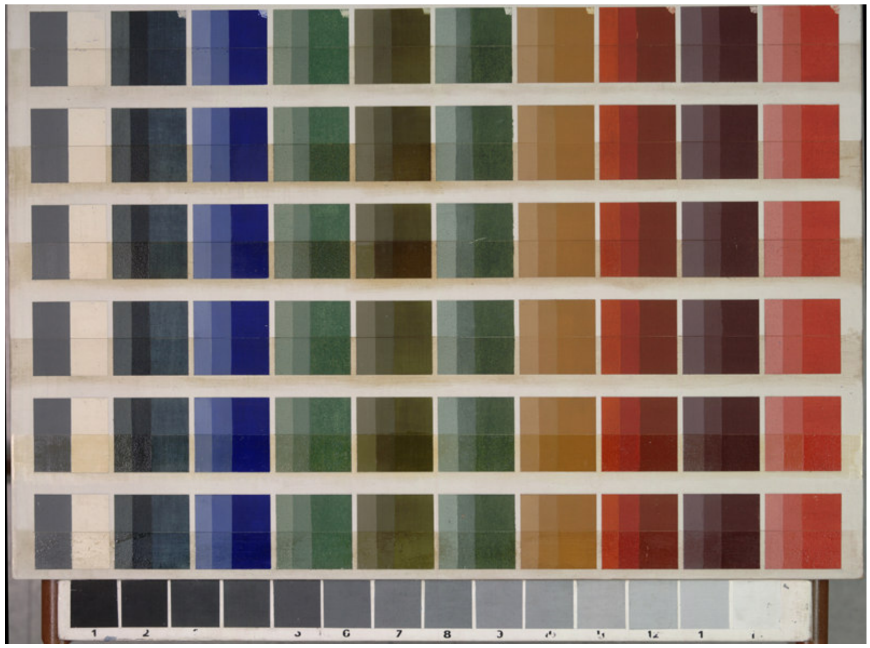


Figure2
Experimental panel (30x45 cm) of model paint/varnish layers similar to those found on icon panels (10 pigments half covered with a layer of 5 different varnishes).

The spatial resolution used for the roughness measurements was 2.3 μm, and the depth resolution was 1 μm. Note that the depth resolution for confocal profilometery depends on the objective lens. Different objective lenses have been tested in capturing the surface of different paint /varnish layers of the experimental panel, in order to assess the experimental possibilities for measuring the roughness of the upper (varnished) or lower (sub-varnish) paint surface. Depth resolutions on a nm scale are possible using confocal white light profilometery, but require working distances of 1 mm or less. This is not acceptable for use with valuable objects, since the danger of accidental contact and damage is very high. However, in cases of studying a painting before and during a conservation treatment such experimental options could be relevant.

Because the FING-ART-PRINT imaging spectral device is not yet available, initial spectral fingerprints were taken using a MINOLTA 2022 portable spectrophotometer equipped with an integration sphere. Measurements were taken in the visible range in diffuse reflectance mode with the following instrument settings: spot size of 4 mm diameter; 2° observer, specular component excluded, spectral resolution of 10 nm between 400 and 700 nm. In terms of spectral resolution, the measurements reported in this communication are considered equivalent to the ones which will be provided with the FING-ART-PRINT prototype. However, the planned spatial resolution of the final spectral imaging device will also be on the order of µm. This was clearly not possible for the current spectrophotometer with a spot size of 4 mm diameter.

Results and Discussion

Typical results of the fingerprinting of the icon "St. Georgios from Ioannina" are shown in Figures 3-8. The surface roughness was measured at several 7 x 7 mm areas as shown in Figure 3a. In order to relocate the fingerprints in the future, digital photographs of each of the areas were taken. The light emitted from the objective lens itself was also photographed, see Figure 3b. The general positions of the fingerprinted areas could then be marked with white squares, Figure 3a, using standard image processing software.

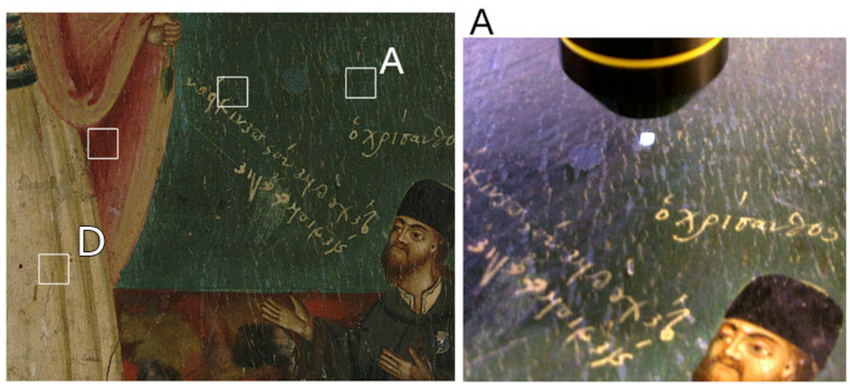


Figure 3
Positions for fingerprinting of the icon "St. Georgios from Ioannina"
(a) Detail of the icon with four selected positions from which fingerprints were acquired
b) Detail showing icon positioned under the confocal microscope stage for roughness measurements (position A in Figure 3a).

A roughness measurement from position A is shown in Figure 4a. The corresponding enlargement of the area is shown in Figure 4b. The roughness measurement is shown as a false-colour microtopographic map of the area, where the colours indicate height, red being high, and blue being low. In Figure 4a, several dark blue areas can be seen which correspond to the places where the varnish has flaked off of the green paint layer of the background, see arrows in Figures 4 a and b. The craquelure network in the roughness map, Figure 4a, can also be clearly related to the digital image in Figure 4b.
It should be noted that the spatial resolution of this map is 1 µm, which is at the level of individual pigment particles. Assuming that someone

even knew where the fingerprint was taken, such a fingerprint would be impossible to forge by hand.

An example of a reflectance spectrum in the visible range taken from a relatively homogeneous area of the icon is shown in Figure 4c. Due to the 4 mm spot size, this is an average spectrum which corresponds to a dark green area in Figures 3a (A) and 4b. Such spectra are also unique for a particular paint, and can thus also be considered as a fingerprint of the (painted) object. The imaging spectral interferometer to be developed for FING-ART-PRINT will eventually provide reflectance (colour) information at micrometer spatial resolution similar to that of the profilometer.

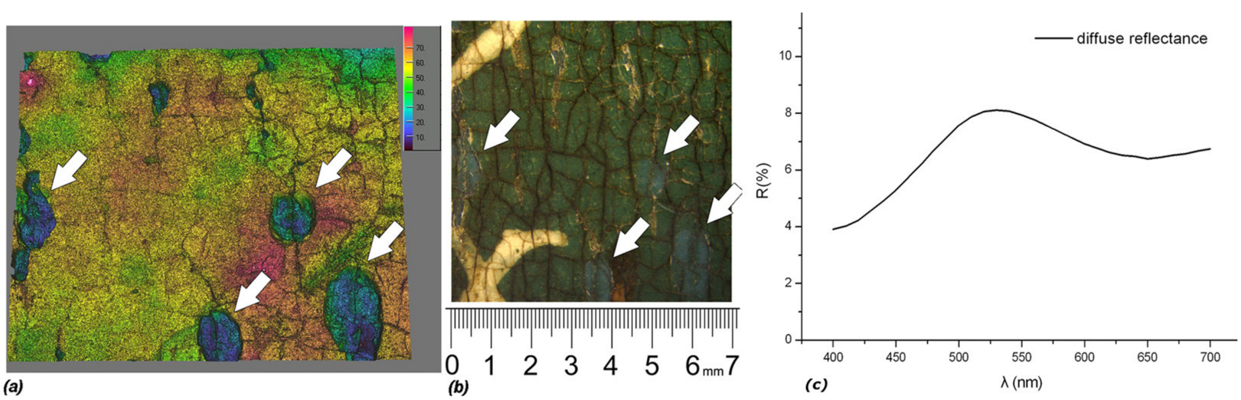


Figure 4
Fingerprint of an area of 7x7 mm, consisting of: (a) False colour roughness map, where blue is low and red is high (red is approximately 70-80 µm higher than blue) and b) corresponding image detail of the measured area A under stereomicroscope; (c) diffuse reflectance spectrum in the visible range of the green area shown in Figure 4b.

Another example for documenting surface defects is shown in Figure 5. Different options for the evaluation of roughness measurements for documenting surface microtopography are shown in Figures 6-8 for the position given in figure 5.

Further work is also being conducted to establish the FING-ART-PRINT technique as part of standard scientific methodology to assist conservators with the proper selection of materials to be used in cleaning and revarnishing.

Figure 5
Detail showing icon positioned under the confocal microscope stage for roughness measurements (position D in Figure 3a).

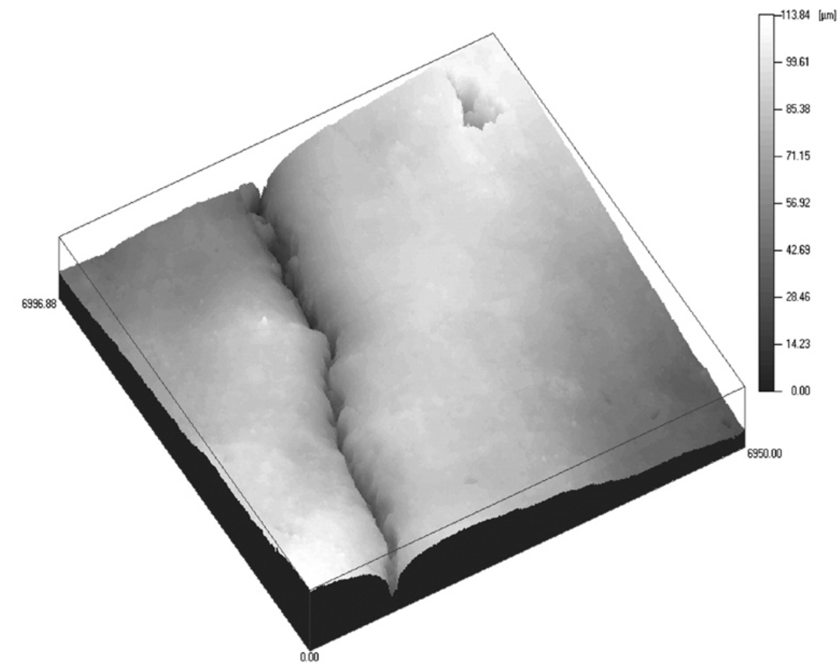
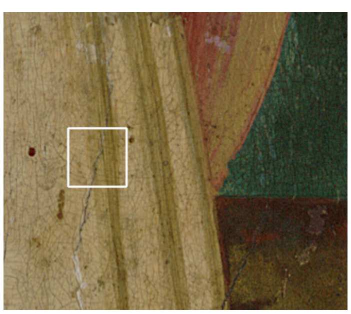
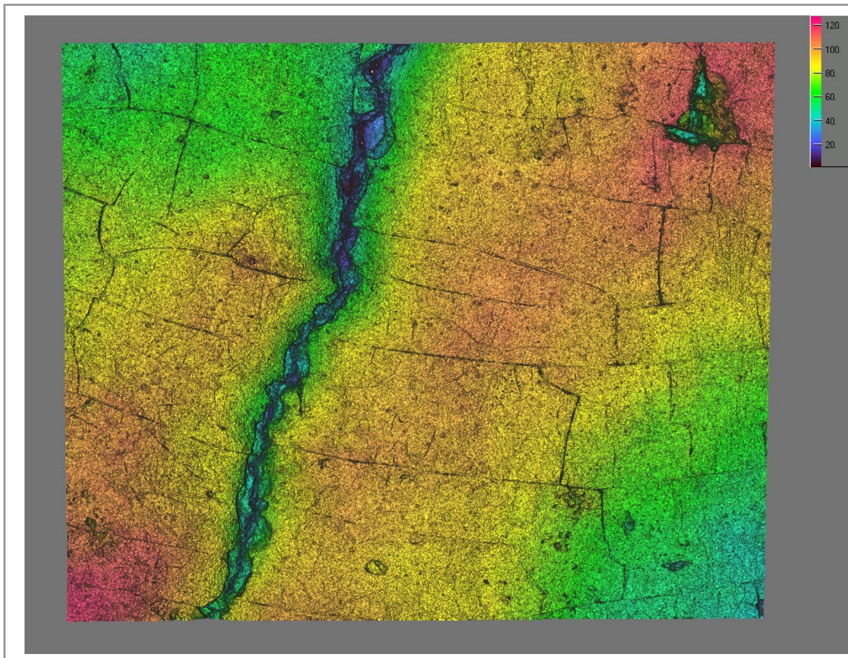


Figure 6
3D view of the area D (Figure 3a) focusing on a crack of the paint surface with the confocal microscope (see Figure5).

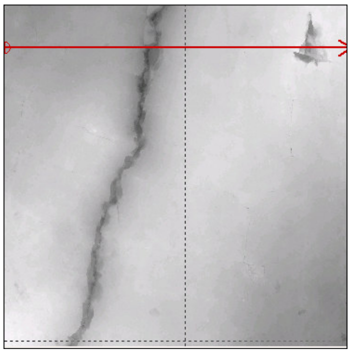


(a)



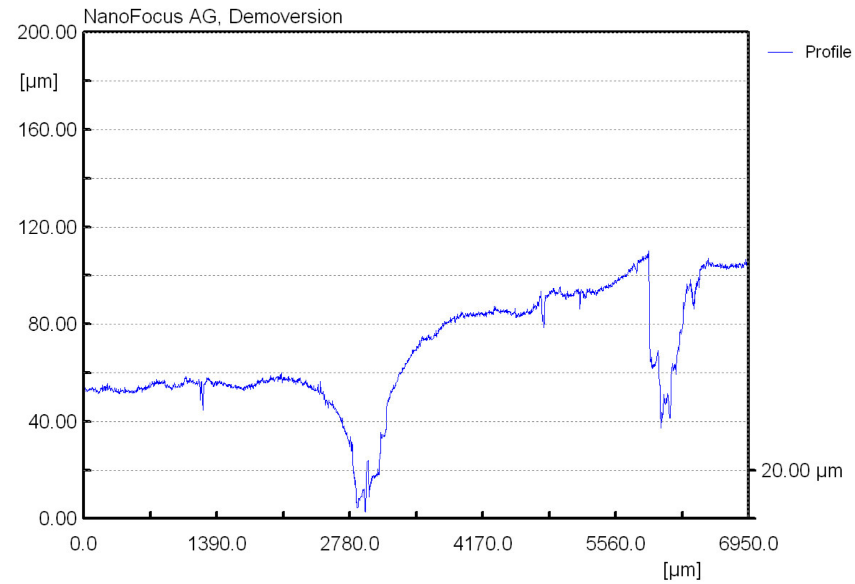
(b)

Figure 7
(a) Detail showing position D (7x7mm) in Figure 3a.
(b) False colour roughness map of the area outlined in figure 7a, where blue is low and red is high (red is approximately 110 µm higher than blue).



(a)

Figure 8
(a)7x7mm detail (the same outlined in figure 7a) with the red arrow showing the position of a surface profile taken within position D (see Figures 3a, 5-7).
(b)Surface profile of the crack at the position shown in the detail in Figure 8a.

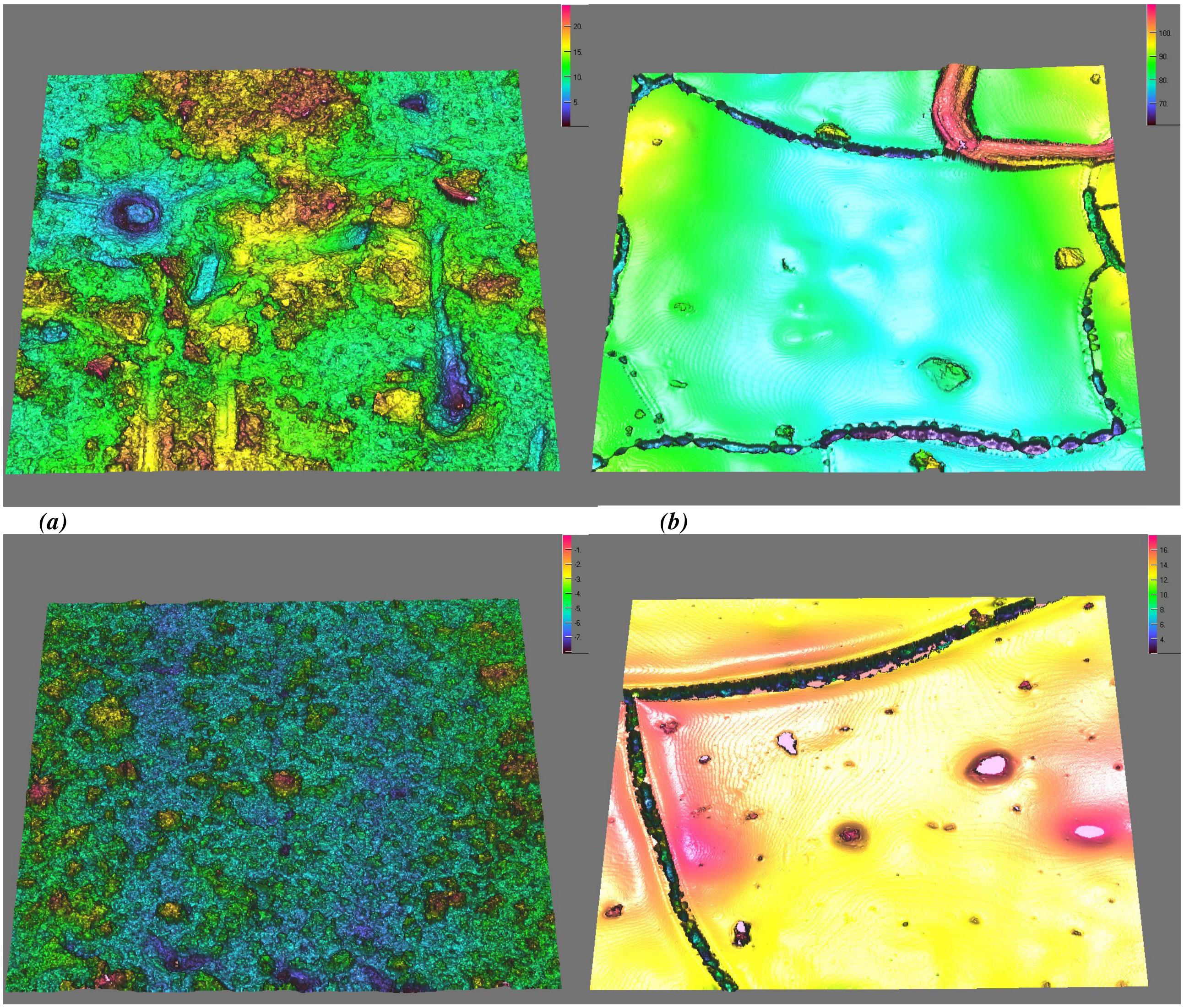


(b)

Experimental measurements have been taken on model samples (see Figure 2) in order to compare the effect of various types of varnish on the colour and surface topography of paints. Examples of the use of the confocal microscope at submicron resolution for the documentation of the roughness of varnish layers or the paint surface are shown in Figure 9.

Next steps are to determine the effect of aging on surface texture and colour of revarnished paintings.

The initial results on icon paintings show that the roughness measurements provide a precise three dimensional reproduction of the surface of an object. Combined with high spatial and spectral resolution reflectance measurements, the object thus provides its own unique identification marking. However, before this technique can be standardized on an international scale, a number of issues must be addressed, including the effects of aging on the fingerprint in the broadest sense of the work, mechanical damage to the fingerprint, and the logistics of the fingerprinting process itself, e.g. making sure to take the fingerprint after a restoration, determining whether the object should be cleaned and thus the subsequent durability of the fingerprint.



(a) *(b)* *(c)* *(d)*

Figure 9
3D false colour images of the surface topography of paints; (a), (b) yellow ochre+lead white and (c), (d) blue ultramarine+lead white; (a), (c) unvarnished and (b), (d) varnished with sandarac.

Conclusion

A novel methodology is being developed within a European project, FING-ART-PRINT, for the non-contact "marking" and identification of objects. Initial work with icons has shown that local roughness measurements taken at 1 μm resolution provide a unique "fingerprint" of the object. When combined with spectral reflectance (colour)

measurements, also at that spatial resolution, an object provides its own unique identification marking. It is expected that the FING-ART-PRINT methodology will constitute an integral part of modern conservation strategies and collections management in the future, allowing the secure and well regulated circulation of valuable objects, and protecting them from theft and illegal trafficking.
Another relevant application of the FING-ART-PRINT methodology is under development aiming at the non-contact documentation and evaluation of restoration work by recording and controlling the progressive steps of conservation treatments. Furthermore, the FING-ART-PRINT system can be used to assist conservators in the evaluation of possible changes in roughness or colour due to conservation treatments (cleaning / consolidation).

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