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Original article

Noninvasive analyses of low-contrast images on ancient textiles: The case of the Shroud of Arquata

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ABSTRACT

We present the results of the first in-depth measurements of the linen cloth of the shroud of Arquata, a precious copy of the Shroud of Turin, which dates back to 1653. The measurements aimed at finding the nature of the faint and low-contrast body impressions on the linen cloth, which are not produced by drawings or paintings as in the other copies of the Shroud of Turin. In general, the optical analysis and the imaging of low-contrast stains on ancient textiles is a complex task, due to the irregular surface and the influence of spectrum, position and uniformity of the illuminating source on colour accuracy and rendition. A correct evaluation requires a multidisciplinary approach. We used noninvasive technologies, including imaging topological radar, laser induced fluorescence, absolute diffused reflectance and absorption spectra, which were previously used to study frescoes, paintings, antique papers, but were never exploited on ancient textiles. The combined results of our measurements and data elaboration allowed identifying the origins of the body impressions, of the stains simulating blood and of the other marks embedded on the linen cloth. Our results can be used to plan the proper long-term conservation of the linen cloth and of marks on it.

1. Research aims

The optical analysis and the imaging of low-contrast stains on ancient textiles is a complex task, due to the irregular surface and the influence of spectrum, position and uniformity of the illuminating source on colour accuracy and rendition. A correct evaluation requires the use of complementary technologies and a multidisciplinary approach. Here, we present an example of complementary equipment and techniques applied to the first in-depth measurements of the linen cloth of the shroud of Arquata, a copy of the Shroud of Turin, which dates back to 1653. The measurements aimed at finding the nature of the low-contrast body impressions on the linen cloth, which are not produced by drawings or paintings as in the other copies of the Shroud of Turin. We used noninvasive technologies, including imaging topological radar, laser induced fluorescence, absolute diffused reflectance and absorption spectra, which were previously used to study frescoes, paintings, antique papers, but were never exploited on ancient textiles. This multidisciplinary study allowed identifying the origins of the body impressions, of the stains simulating blood and of the other marks embedded on the linen cloth. In addition, the results allowed developing a plan for the proper long-term conservation of the linen cloth and of marks on it.

2. Introduction

The Shroud of Turin is a linen cloth bearing the front and back body images of what appears to be a crucified man. Since the XVI century, many copies of the Shroud were painted, but only 50 survived to date [1]. One of the most interesting copy was discovered in 1980, during the restoration works of the church of St. Francis in Arquata del Tronto, near Ascoli Piceno, Italy. The linen cloth was hidden inside a niche along with a parchment, which states that during the Holy Shroud exhibition in Turin on the 4th May 1653, a copy of the Shroud 20 palms long and 5 palms wide was put in

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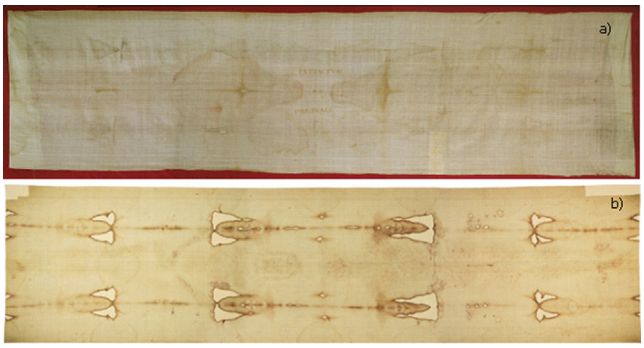

Fig. 1. a: photograph of the shroud of Arquata. The colours are balanced on the reference white. The 4.8-m long linen cloth, sewn on a cloth of red silk, is 1.1 m wide and is folded at the extremities to have an apparent length of 4.4 m, like the Shroud of Turin. Photo ENEA; b: photograph of the Shroud of Turin.

contact with the Holy Shroud. At the end of ceremony, the copy was given back to friar Massimo Bucciarelli, brother of the Bishop Giovanni Bucciarelli. The parchment is signed by the Bishop of Alba in 1655. When Bishop Bucciarelli died in 1656, he left the linen cloth to the Franciscan Friars who preserved it in the convent of St. Francis, at Arquata. Since that time, documents on the shroud of Arquata are sporadic, and inhabitants of Arquata lost the memory of this copy, till the discovery in 1980 [2].

The most peculiar feature of the Arquata shroud (AS) is the front and back body impressions that do not show perceptible drawings or painting that are evident in the other copies of the Turin Shroud [3] see Fig. 1. In a sense, the AS is the most similar copy of the Turin Shroud because even the body images on the Turin Shroud are not painted nor drawn [4].

The analysis of faint images and stains embedded on ancient textiles like the AS by optical tools is a challenging task, as discussed in [5,6]. To face this issue, we used two multispectral imaging techniques such as imaging topological radar red-green-blue (RGB-ITR) and laser induced fluorescence (LIF) linear scanner, and one diagnostic technique such as the absolute diffuse reflectance spectroscopy. These techniques were chosen because they are complementary, allowing both morphological and physical-chemical characterization of the sample under study. These pieces of equipment were successfully applied to noninvasive analyses of cultural heritage like, e.g., frescoes and paintings [7,8] or ancient papers [9–11], yet this is the first time they are used to analyse ancient textiles.

3. Analysis and imaging of the linen cloth

Measurements were performed inside the church of St. Francis in Arquata, where the AS is exposed to public in a frame covered by a 10-mm-thick glass. The cover glass was removed from the frame, and we were not authorized to unstitch the AS from the underlying red silk fabric.

Direct inspection with the aid of a magnifying glass and analyses of macro-photographs of the linen cloth revealed it is a plane weave, warp (2.6/mm) perpendicular to weft (2.7/mm) and the average filling factor of the texture is 83%. The average thickness of the cloth measured by a calliper for textiles is 0.27 mm, and we can estimate its dry weight to be about 1.95 kg.

At a visual inspection, we observe the lack of anatomic details in the body impressions, which makes the AS very different from the other copies of the Shroud of Turin [3]. In the centre of the cloth between the imprints of the head there is a Latin inscription in capital letters “EXTRACTUM AB ORIGINALI” (derived from the original) confirming the AS was put in contact with the Shroud of Turin, as stated in the parchment mentioned in §1.

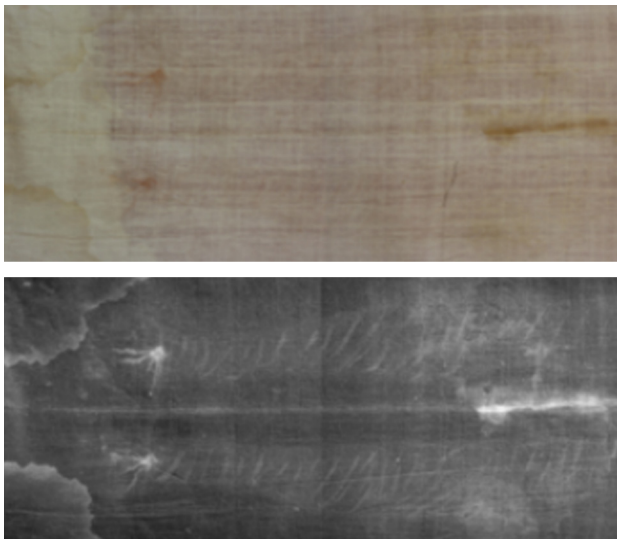

Fig. 2. Above: photograph of the front image of the legs and feet. Below: the same photograph subtracting components blue and red (B-R). The image B-R highlights the thin brush marks that simulate the scourging on the legs, which are barely visible in the picture above and allows to see the outlines of the feet, heel, toe, individual fingers, which are invisible to the observer.
Photo ENEA.

Macro-photographs show that the average thickness of warp yarns is 0.15 mm and 0.255 mm, respectively inside and outside the body-shaped impressions. The average diameter of weft yarns is 0.25 mm everywhere. As a consequence, the area inside the body impressions is more transparent than the remaining part of the cloth, and the red silk underlying the AS contributes to the perception of darker-than-background body impressions.

Using a magnifying glass, we observed faint and thin reddish marks on the legs, which simulate blood from scourges. They are almost invisible in contrast-enhanced photographic images. To make them visible, we disassembled the photo in red, green and blue (RGB) components and operated the difference blue minus red (B-R). The painted thin scourges and details of heels and halluces emerge in the B-R image, see Fig. 2.

The same B-R image processing of the photograph of the face provided an interesting clue on the technique used to create the body image: in fact, the processed image B-R points out signs attributable to abrasion and liquid steamers along the warp yarns, see Fig. 3.

4. Imaging topological radar

The RGB-ITR is based on the amplitude modulation technique and the use of three combined laser sources (red = 660 nm, green = 532 nm, blue = 440 nm) and photodiode detectors. It scans the target collecting simultaneously colour and distance information, without being influenced by ambient illumination. The modularity of this system permits to replace the colour sources with a near-infrared (NIR) laser emitting at $\lambda = 800$ nm, which is relevant for hidden details detection. The RGB-ITR offers the possibility to monitor the evolution of deterioration caused by physical and chemical agents [8] or to highlight changes, if any, caused by restoration works [12]. The RGB-ITR digitized the 5 m^2 surface of AS in about 12 hours with a spatial resolution of 0.6 mm at a distance of 5.5 meters. Fig. 4 shows a view of the AS and a zoom of the central portion of it.

Infrared imaging is used in art history and restoration to reveal details hidden under the paint. Part of the NIR is transmitted through the paint layers and is reflected by the substrate of the

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