A study of the front and back body enveloping based on 3D information

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SUMMARY

A response to the possible enveloping of the Man of the Turin Shroud results from the analysis of the three-dimensionality of the body image. The 3-D analysis is based on the correspondence between image luminance levels and body-sheet distance.

The sum, point by point, of the body-sheet distance, measured on the basis of the luminance levels, with the corresponding position of the external surface of a man gives the Turin Shroud outline of the enveloping.

The frontal and dorsal body images were trimmed of different noises such as traces of water, blood, fires, etc.; such images were then reconstructed for the lacking parts (arms) through a kinematic analysis associated with a computerized anthropometric analysis.

On the basis of experimental data, some points were chosen in which the body-sheet distance is lifelike and the condition is set so that a defined measured distance must be associated to the corresponding levels of image luminance. From the analysis of the luminance levels, segments reconstruct the assumptive distance between the Man and the sheet.

From the three-dimensional analysis it is confirmed that the Man was not enveloped in the Turin Shroud with bandages. The sheet was simply laid on the outstretched body, in a position conformable to the one taken on during the crucifixion (except the arms) and maintained during the entombment because of the strong *rigor mortis*.

1) INTRODUCTION

The **TS** (Turin Shroud) is a work "not made by human hands" that has the particular characteristic of not imposing but proposing itself. Science has underlined many particularities that show that it was the burial sheet of Jesus[1], but none of them, taken singularly, represent proof so overwhelming to clearly show the truth. This is a particular aspect that must have been selected by the One Who "made" the Shroud imprint so that whoever wants could believe, but whoever wants to stay sceptic could choose freely to stay so.

Even if the frontal and dorsal imprints of the TS were really caused by its enveloping a human body, there is still someone who maintains, against the common scientific opinion, that the imprint is a painting[2]. That the body imprints were caused by the enveloping of a human body is shown by different factors among which is the elevated anatomical detail, unthinkable for a medieval artist, but at the same time the presence of evident distortions (calves, hands and back) that any artist would have avoided if they were not caused by the body-sheet enveloping.

The frontal image of the TS, 1.95 m long, is not directly compatible with the dorsal image, 2.02 m long. To verify the possibility that the same human body generated both images, a numerical anthropomorphous manikin was built and enveloped with the frontal and dorsal digitalized images[3]. From the analysis performed, the frontal and dorsal images turned out to be compatible with the enveloping of the body of a man 175±2 cm tall who, due to cadaverous rigidity, stayed in a position (excluding the arms) the same as the one he could have taken on during the crucifixion. The

position of the **MTS** (Man of the Turin Shroud) was valued in terms of the angle of the legs, of the arms and of the inclination of the head.

Science is still not able to explain how the body image could be really formed and has formulated different hypotheses[4]. The most reliable one, even if not demonstrable, is that based on an explosion of brief, but intense energy, perhaps correlative to the Resurrection, deriving from the inside of the enveloped body[5]. The energy, probably also luminous, could have interacted with the aloe and the mhyrr present in the sheet to cause the acid oxidation of the flax fibrils[6]. According to other authors[7], however, the energy could have been propagated in the flax fibrils (oxidizing them) in the same way as photons propagate in optic fibers until they find a discontinuity. This would explain why the beard and hair are engraved on the TS in such a well definite way.

In any case the most likely way, also if not yet completely demonstrated with experimental tests, is that of thinking the body image of the TS was produced by a source of energy inside the enveloped body.

Many hypotheses were formulated about the mechanism of the image formation[8], and a very enthralling one is that of J. Jackson[9] according to whom the body image could have been formed during the collapse of the sheet, that fell through the enveloped body become mechanically transparent. This hypothesis does not however seem consistent with the luminance levels of the resulting image: if the face image is considered, for example, it is possible to make reference to the scheme of figure 1. If sheet A had caused the body image by falling through the head, the luminance of the corresponding face image should have a minimum value not inferior to the relationship of the B/C segment. Therefore we would not be able to observe the level of detail that really is observed because the image would be all uniformly darker. For example, in the zone of the eyes, the luminance varies from a value of 60 to a value of 120 in a digitalized image in black and white with 256 grey levels; the relationship between minimum and maximum value is therefore 50%. Obviously the relationship of the B/C segments of figure 1 is superior at 50%.

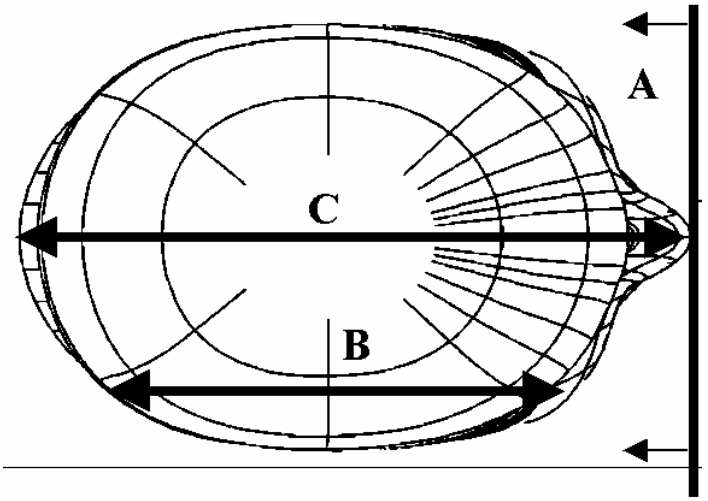


Figure 1: Scheme of a head of a man with sheet A that would fall through it according to the hypothesis of J. Jackson of the "man become mechanically transparent".

The hypothesis of the image formation by means of an explosion of "vertical" energy[10] is the one most considered in a scientific environment because the frontal and dorsal body images appear similar to a vertical projection. If, however, some zones of the Shroud image are analyzed in detail, geometric distortions are observed not completely coherent with a simple vertical projection (see, for example, the zone of the head, calves, arms, hands and back). The result of the Shroud image, therefore, was not necessarily caused by a vertical projection, but perhaps by the normal to the local skin surface during a particular enveloping of the MTS in the sheet.

How was the MTS enveloped? Till now not many detailed studies[11] have been done to answer this question. Starting from the hypothesis that the TS really enveloped a man, many scientists have supposed that the sheet enveloped the body completely. There is even someone who sees the sign of the strings that closed the sheet around the legs[12]. According to a recent study[13] the sheet was simply lying on the body and was not positioned on a flat surface under the MTS, but enveloped the body partially because the MTS was lying on a hollow or soft bed (for example a bed of flowers or aromas[*]). According to the authors of the present work, the sheet could have been simply lying[**] on the MTS without any contact on the sides: this is the explanation of the imprint similar to a vertical projection without there necessarily having to have been a source of vertical energy.

The present study will try to go into this problem.

2) METHOD

Figure 2: Three-dimensional elaboration of the MTS face on which the traces of blood were repositioned considering the effect of the cylindrical distortion due to the enveloping of the sheet.

The body image has three-dimensional characteristics in the sense that the levels of luminance correspond somehow to the **bsd** (body-sheet distance). It is necessary, however, to clarify the law (linear, quadratic, logarithmic, etc.) that defines a one-to-one correspondence between the luminance levels and the bsd. Beyond this, it is not still clarified if the explosion of energy that caused the body image is an explosion of a volumetric type, in the sense that all the body emitted an

[*] The literal version of the Jewish text of 2Cr 16:14 that describes the burial of Asa, king of Judah (909-870 B.C.) is interesting: "They deposed him on a pallet that was *full up of aromas and kinds of aromatic herbs mixed with work of aromatic mixture*" (M. L. Rigato: "La sepoltura regale e provvisoria di Gesù secondo Gv 19,38-40". Atti del VIII Simposio di Efeso su S. Giovanni Apostolo, Pontificio Ateneo Antoniano, Roma 2001, pages 53-54).

[**] This hypothesis does not oppose the descriptions of the evangelists. Particularly the term *othonia* used by John must not be translated *bandages* but *linens* (M. L. Rigato, *op. cit.*, page 74) and the plural in relationship to the Shroud "makes sense if we think to a quantity of *linen cloth* equivalent to a measure at least double than that served normally for a single «othonion»" (M. L. Rigato, *ibid.*, page 71). The interpretation of another bible scholar, G. Ghiberti, is similar. He considers the dead man "not completely enveloped but only making the sheet go up behind the head of the dead man, to cover him only frontally" (G. Ghiberti: "Sindone verso il 2000". Edizioni Piemme, Casale Monferrato - AL 1999, p. 23). The plural used by John is so explained: "If we imagine a piece of long cloth laid under a body and then made to go up behind his head and laid on the same body, we have the impression of a sheet on the body and another under it and then we can speak about sheets in the plural" (G. Ghiberti, *ibid.*, pag. 25).

energy able to oxidize the fibrils of flax or of a superficial type in the sense that the body image corresponds to the effect of the so-called "bright Man" who emanated energy from his surface with the emission of wide band radiation[14].

Another problem to solve is that regarding the possible different position assumed by the TS during the transposition of the blood by fibrinolysis and during the formation of the body image. For example, according to G. R. Lavoie et al.[15], the traces of blood that are seen in the hair of the MTS correspond to wounds positioned on the cheeks. The distortion of cylindrical type due to the enveloping of the face indeed makes traces of blood from the cheeks move to the corresponding position in the hair if the sheet places itself according to a horizontal plane, tangent to the forehead and the nose (see figure 2).

The present paper does not intend to solve all the problems posed but tries to answer some questions. To do that, we proceeded in the following manner, shown in figure 3.

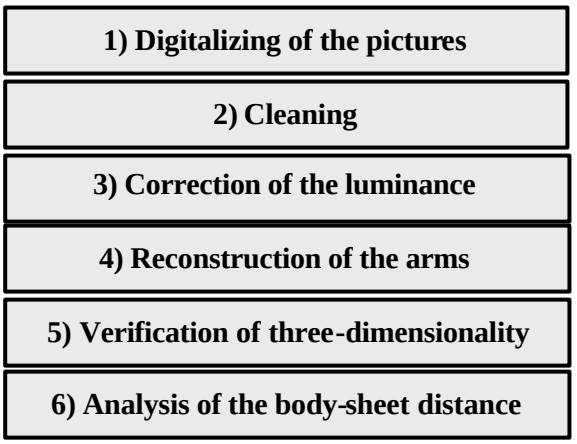


Figure 3: Scheme of the procedure followed.

The work starts with the digitalization of the photos of the MTS frontal and dorsal images. The photos chosen were obtained by contact with the plates performed in the 1931 by Enrie with orthocromatic film (granted by the Scoffone studio of A. Guerreschi) because they are characterized by excellent resolution over all the surface.

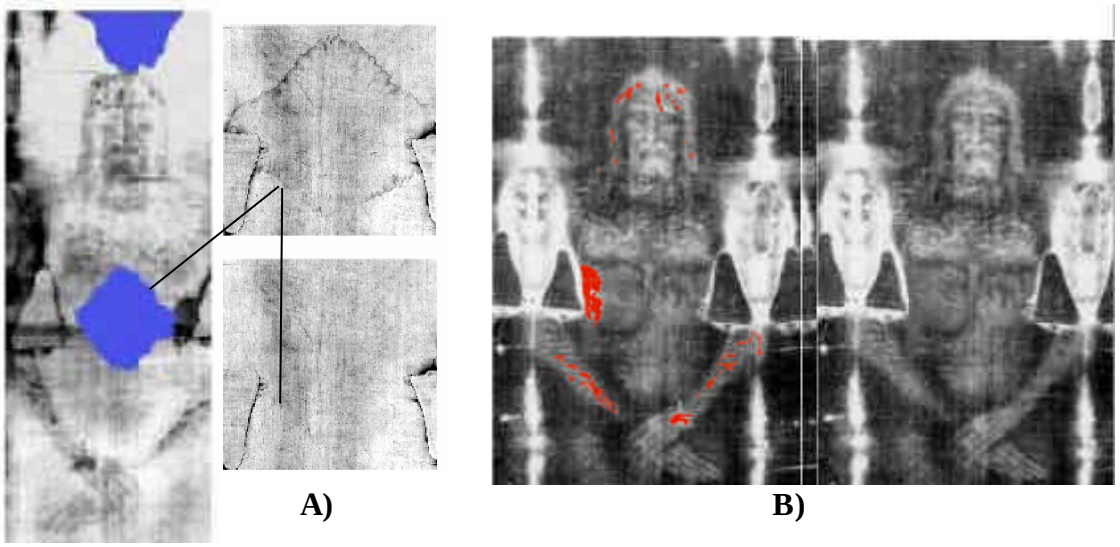


Figure 4: Examples of cleaning of the digitalized image. A) Removal of the traces of water; B) Removal of the blood: the mean characteristic luminance of the blood stains turns out to be equal to 207, while the mean luminance of the whole image is equal to 96; the isolation of the defect to proceed to the correction is therefore easy.

The resolution is in fact better than the weft of the linen fabric and therefore, with these images, it is possible to analyze photographic details of about half a millimeter, with a length of the fabric of 5.34 m.

The frontal and dorsal images were digitalized, acquiring the whole sheet in 24 images of dimensions of 7 MB. The frontal and dorsal images were then cleaned[16] of the different defects and noises such as the traces of water, blood, etc. that heavily deteriorate the quality of the body image there represented (see figures 4 and 5).

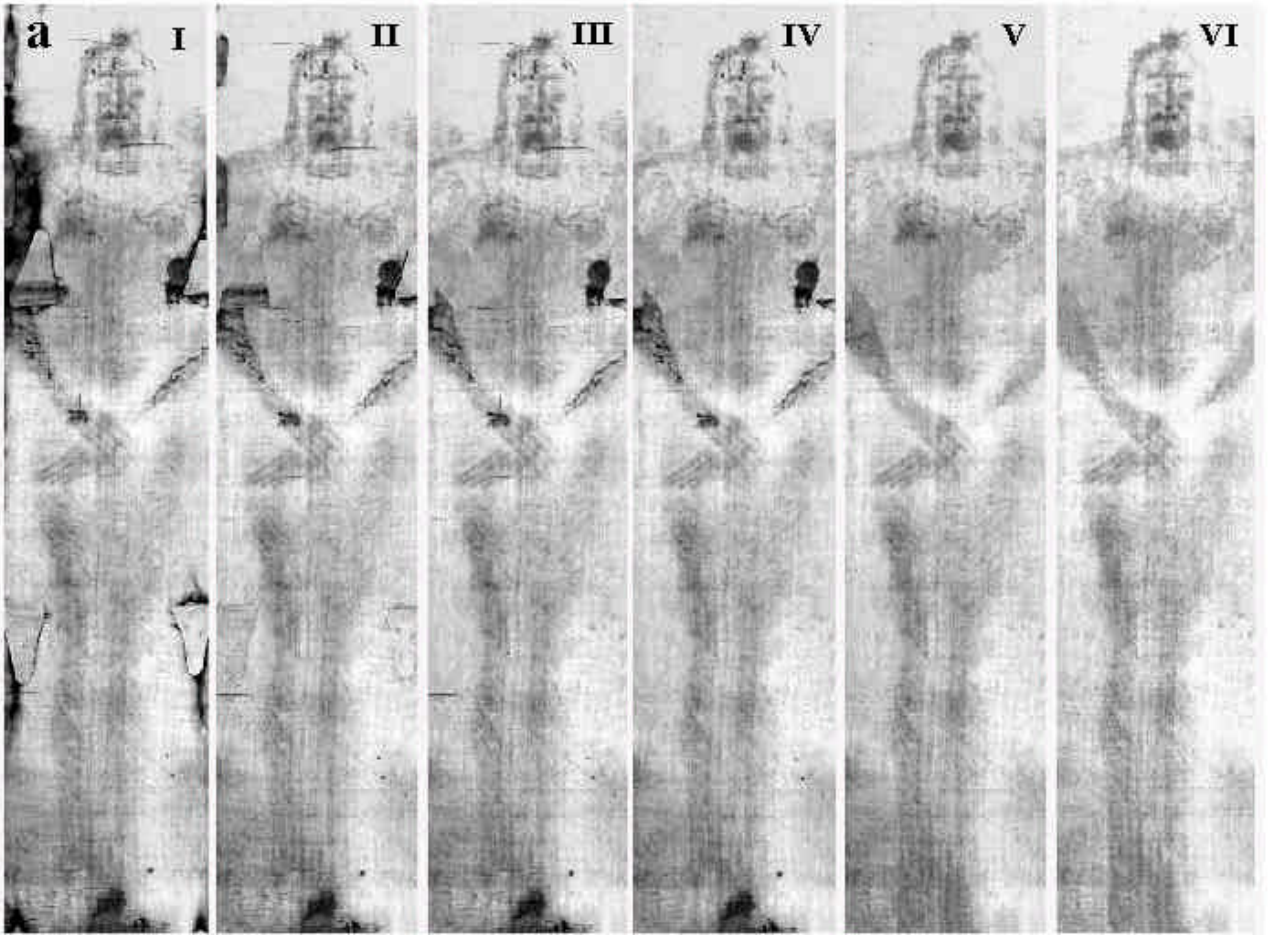


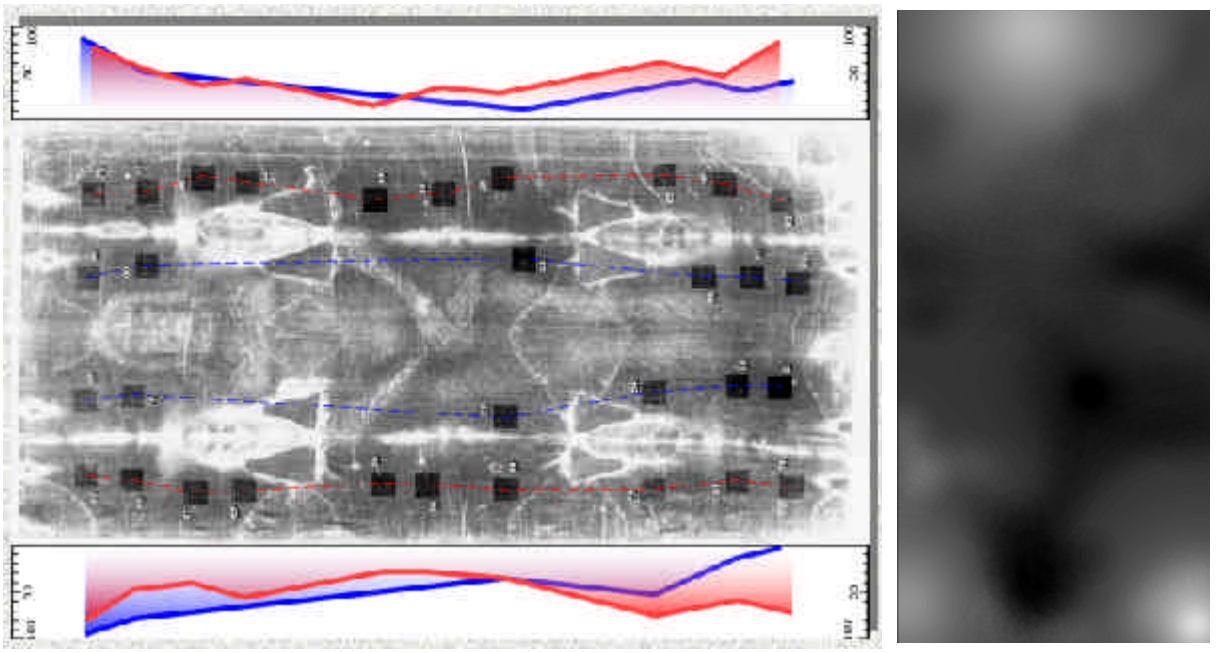
Figure 5: Phases of correction of the frontal body image: I) Initial image; II) Cleaning of the traces of water; III) Cleaning of the scorches and elimination of the patches; IV) Cleaning of the folds; V) Elimination of the blood stains; VI) Elimination of the wounds.

The digitalized image was then corrected[17] in the luminance values to consider the non uniform effect of illumination. In figure 6 the method based on the hypothesis that the background of the sheet is characterized by a mean uniform value of luminance is shown.

In the same way an anthropomorphous manikin[18] with the dimensions measured on the TS body images, that could be animated according to the kinematisms of a human body, was computer built. The kinematic model was realized using Poser software on the basis of the choice of a long-limbed and muscular body typology. We assumed the hypothesis, confirmed by forensic analysis[19], of a man enveloped in the TS with characteristics of strong cadaverous rigidity. A confirmation of the hypothesis was obtained observing the conformation of the buttocks image that, contrarily to what would be expected, does not present signs of crushing due to the body weight. The manikin can be

modified as to dimension in conformity to the anthropometric parameters measured on the TS (see figure 7).

From the analysis of the different luminance levels of the digitalized images, the profile of the frontal and dorsal body images was determined, and finally, from this the relative anthropometric points were defined to be used for the numerical sheets and the numerical manikin.



A) **B)**

Figure 6: Phase of correction of the luminance levels. A) Acquired image and course of the values of luminance relative to 4 definite segments on the TS, frontal image. B) From the hypothesis of the uniformity of the background luminance values, the mask, corresponding to the probable non-uniform illumination, was built. The result of the Shroud image is obtained from the difference between the luminance values of image A and the ones of image B. The same procedure was used for the dorsal image.

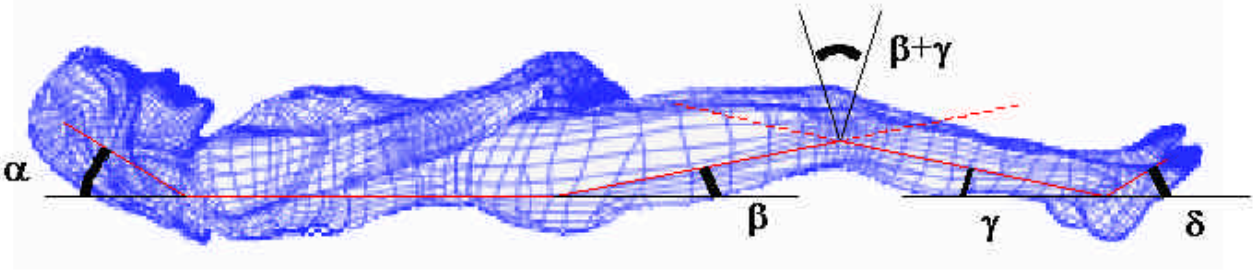


Figure 7: Angular positions (α = angle of the head, β = angle of the femur, γ = angle of the tibia and δ= angle of the feet) that were varied to verify the existence of the compatibility between the anthropomorphous manikin and the frontal and dorsal body images of the TS.

Some anthropometric points, relative to the shoulders and the arms, that are not visible on the body image of the TS, were reconstructed through an iterative procedure based on the overlap of the sheets on the manikin.

Two numerical sheets were built, one for the frontal image and the other for the dorsal one. A certain plasticity of the sheet that covers the body was hypothesized, like a damp sheet. The

coordinates of the anthropometric points previously determined in the frontal and dorsal images of the TS and other characteristic points of the profile of the image were settled on the two numerical sheets (see figure 8).

The position of the manikin was adjusted comparing the corresponding profiles, defined on the frontal and dorsal images, corresponding to the zones of equal values of luminance (see figure 9). It was hypothesized that an equal distance body-sheet corresponds to areas of equal luminance of the body image

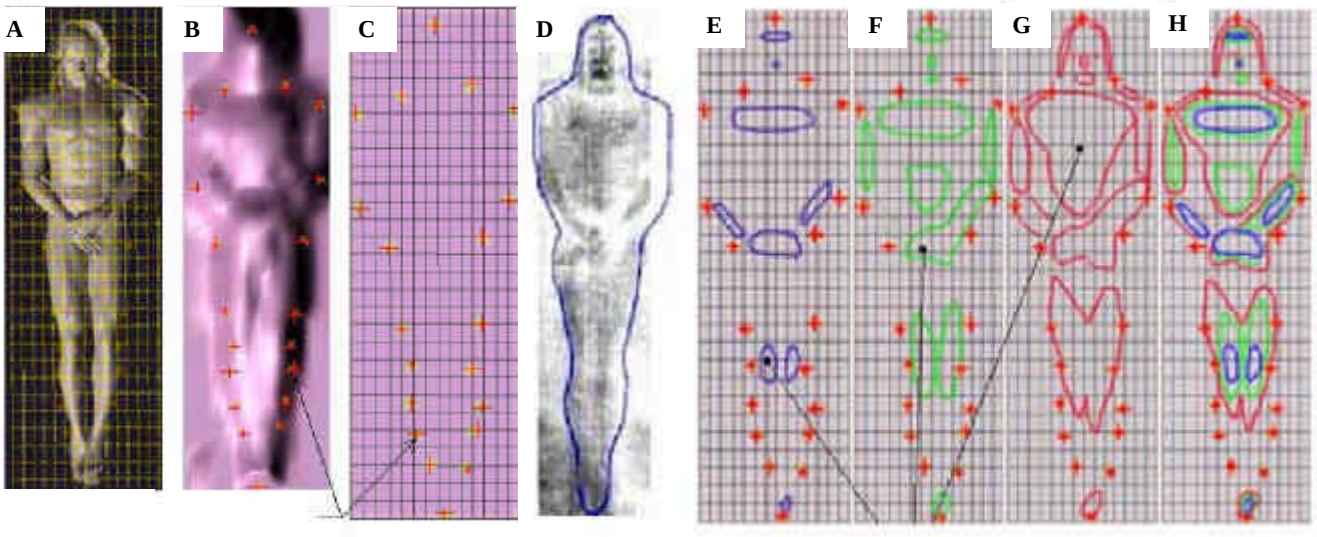
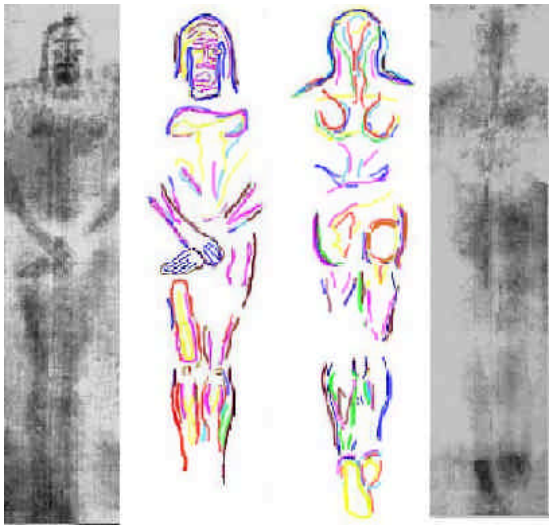


Figure 8: Overlap of the manikin with the numerical sheet of the frontal image with the anthropometric points and the profile of the body image previously determined on the TS (the same procedure was performed for the dorsal image). - a) numerical manikin; - b) manikin covered by the numerical sheet; - c) anthropometric points defined on the numerical sheet; - d) the profile was superimposed on the body image; - e) the numerical plastic sheet was lowered 2 cm in the direction of the manikin in order to determine the zones of contact between body and sheet; - f) lowering of 4 cm; - g) lowering of 6 cm; - h) overlap of imprints e), f) and g).



Intervals of luminance values
70-90
90-110
110-120
120-130
130-140
140-160
180-200

Figure 9: Different color lines are underlined areas on the frontal and dorsal images of the TS with levels of luminance included between the corresponding values pointed out in the table. To such zones would correspond equal body-sheet distances.

The anthropometric data of the two numerical sheets were used to define the dimensions and the preliminary position of the anthropomorphous manikin.

Once the manikin was built, a kinematic analysis to determine the most probable position of the shoulders and of the arms was performed in conformity to the known position of the hands and of the forearms. The kinematism uses the information of the frontal and dorsal images of the TS, while the unknown data are the angular positions of the upper limbs. On the frontal and dorsal images the position of the hands and the lengths of the AB and CB limbs that measure 35 ±1 cm and 26 ±1 cm respectively were valued (see figure 10A). The width of the shoulders (distance between the points A and A* akromion), can be valued on the ground of the following considerations: on the dorsal image the profile of the shoulders is evident; on the numerical anthropomorphous model an equal width of 51.0 ± 0,5 cm results; from a series of measurements on adult males it tourned out that segment AD in adult males is (35% ±2%) of the AA' segment. Therefore AD = 18.0 ±1,5 cm. On the ground of these results the possible limit profiles are obtained for the frontal body image from the TS (see figure 10B).

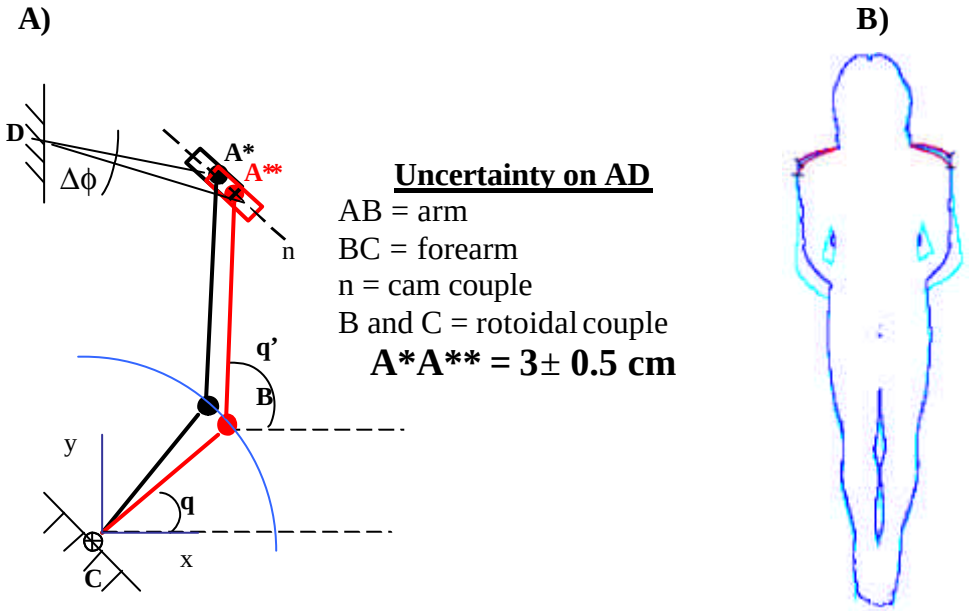


Figure 10: - A) representation of the kinematism of the upper limbs considering the uncertainty of point A with the variation in the length of segment AD;
- B) variation of the body profile of the frontal image in function of the uncertainty of the determination of point A.

The two frontal and dorsal numerical sheets were superimposed on the anthropomorphous manikin to verify if a position of the manikin exists which could simultaneously verify the compatibility of all the anthropometric points defined both on the manikin and on the frontal and dorsal sheets. On the ground of the congruence determined between the position of the anthropometric points of the sheets and that of the manikin, the dimension of the limbs and the angles of the relative inclination of the head, of the knees and of the feet were defined.

The angular position of the limbs was determined considering the extensions or shortenings of the frontal and dorsal sheets. We hypothesized the absence of the sheet folds that would be likely if the body had simply been laid on the sheet and if this was then subsequently laid on the upper part of the body without enveloping it completely on the sides. The hypothesis can also be derived from some global observations on the body image that would make it less coherent with a complete

sideways enveloping: in this case, in fact, also in the hypothesis of vertical radiation[20], according to the authors, the area of the body engraved sideways should be wider.

Once verified the possibility of building an anthropomorphous manikin simultaneously compatible with the enveloping of the frontal and dorsal images, the most probable dimensions and position of the MTS were defined (see figure 7).

The frontal image, 1,95 long, and the dorsal one, 2.02 m long, are therefore compatible with the enveloping of a human body, with an uncertainty level of ±2 cm. On the ground of this analysis, it was possible to determine the physical characteristics of the man enveloped by the TS. The man turned out to be 175±2 cm tall, laid out in a position compatible with that of a crucified man (except the arms) with the feet extended (of 34° and 30° ± 2°), the legs partially flexed (angle of the knees 19.5° and 23.5° ± 3°) and the head flexed upwards (of 30° ± 4°).

From the overlap of the numerical sheets on the manikin (see figure 11 A), it was observed that the frontal and dorsal body images of the TS present a distortion owing to the enveloping of the sheet around the body. As in the case of orthogonal projection[21] in reference to the figure 11 B, one notes that the enveloping of the sheet around the body causes a distortion of approx. 10% more as regards the corresponding dimensions projected on a plane.

Since also the dorsal image of the TS presents the distortion correlated to the partial enveloping of the sheet, it is unlikely that the body of the MTS was laid on a flat surface, on the contrary the surface was hollow, a trough bed (see figure 11 C).

This hypothesis is in accordance with the following possibilities:

-a) that the MTS was laid on a flat surface covered by flowers, since different pollens and remains of flowers that bloom in Palestine in the Easter period[22] were found on the TS, or

-b) that he was laid on a flat surface covered by natron (salt composed of calcium, sodium, potassium and magnesium carbonate, used in Palestine for the burials) since traces of this salt were found on the TS[23].

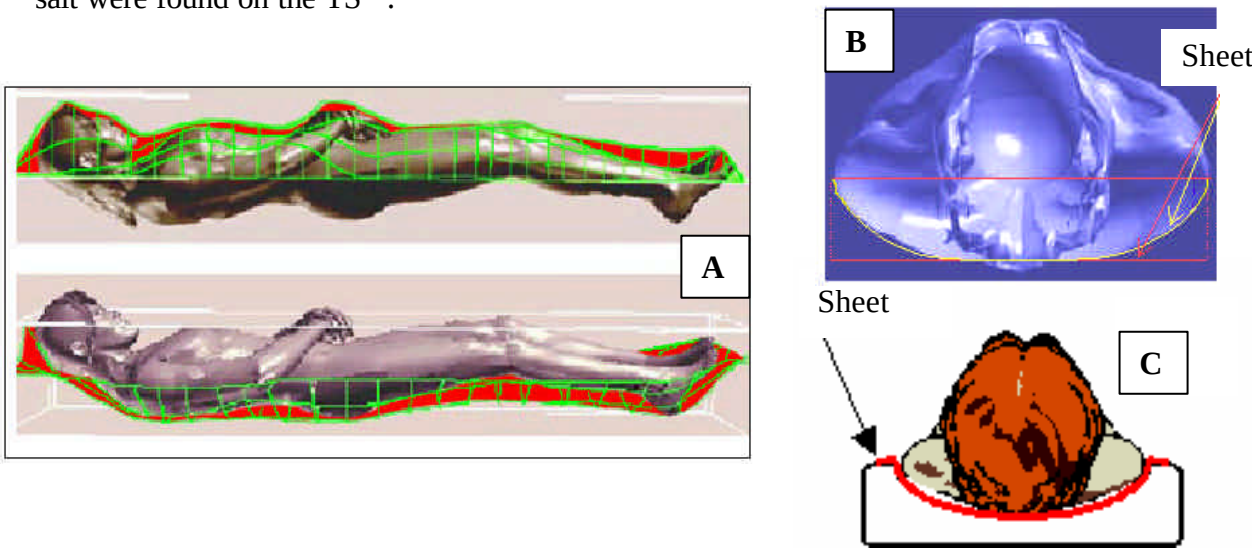


Figure 11: - A) numerical manikin enveloped with the frontal and dorsal sheets; the maximum distance between sheet and body in the frontal image happens in correspondence with the feet; in the dorsal image in correspondence with the flexed knees; - B) trunk of the anthropomorphous manikin seen from the top: the corresponding image engraved on an enveloped sheet (in yellow) is wider because of the effect of enveloping; - C) hypothetical trough bed on which the MTS could have been laid.

In figure 12 are given the results of two independent operations of reconstruction and cleaning of the body image and the result of a three-dimensional elaboration based on the reconstructed images.

This elaboration underlines the different position of the sheet as regards the body better than previous studies, performed on the non-elaborated images[24], even in the back image that seemed to be characterized by an elevated leveling[25].

The result of the rebuilding of the MTS body image is compared in figure 13 with that obtained independently by the sculptor Enrico Manfrini, who made a bas-relief representing the frontal upper part of the MTS.

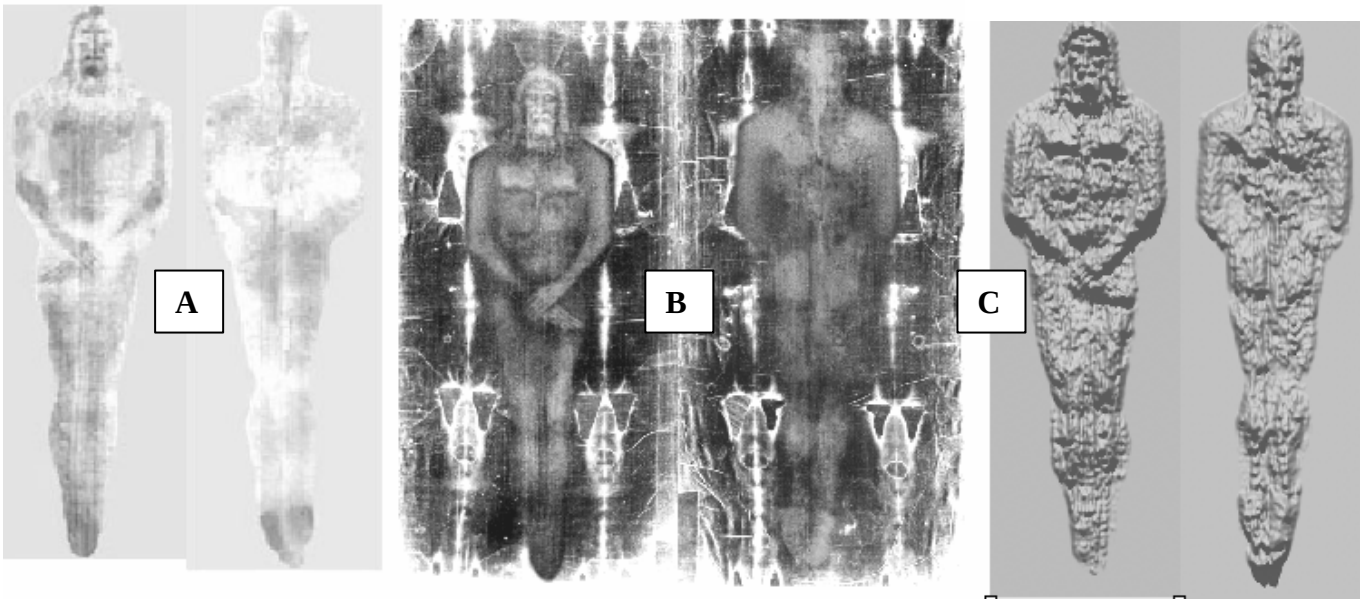


Figure 12: - A) and - B), two independent elaborations of the reconstruction and of the cleaning of the MTS body image; - C) three-dimensional elaboration of the figure (B).

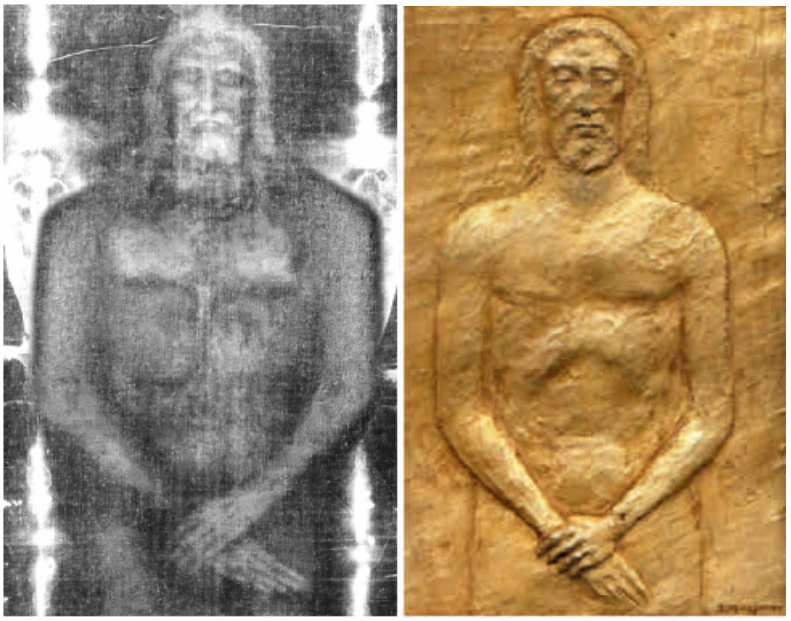


Figure 13: Comparison between the computer reconstruction of the arms and the reconstruction performed by the sculptor Enrico Manfrini (sculpture kindly furnished by Dr. Bruno Mancini of Senesi): the less ample bust, the shorter forearms and the longer neck in the bas-relief should be noted.

From the comparison the following elements could be observed:

- the less ample bust of the Man of the bas-relief is probably the result of the distortion correction due to the enveloping of the sheet;
- the forearms, that are longer in the computerized rebuilding, are affected by a similar distortion;
- the neck, almost lacking in the TS, has been probably corrected in the sculpture to take into account the position of the MTS's head flexed upwards.

The corrections made by the sculptor in the bas-relief are then in agreement with the result of the reconstruction of the TS body image, performed digitally and that obviously should not correct the distortions due to the enveloping of the human body.

3) RADIATIVE HYPOTHESIS

As discussed in the Introduction, the most likely hypothesis of the body image formation supposes the existence of an energy radiation as the image is only explainable if the presence of a phenomenon that acts in the distance is hypothesized[26].

From studies[27] based on experimental tests on men, a correlation between the luminance of the body image and the bsd was performed; we hypothesized a source of energy purely vertical to explain the formation of the body image.

In Ref.[28] a relation between the luminance and the bsd is determined that can be approximated to a curve proportional to $1/d^2$ (being d the distance); the approximation then seems coherent with the law of quadratic propagation of the energy at a distance. In Ref.[29], however, the same luminance-distance correspondence is made linear with a coefficient of determination r^2 (correlation coefficient squared) equal to 0.60. This relation is used to determine, for extrapolation, "the distance at which the regression line intersects the average sheet background intensity" calculated as 3.7 cm, but with an uncertainty that could also be approx. 50%. The dispersion of the results is relatively elevated probably because of the presence of noises in the body image due to traces of blood, water, etc; this is why the present study came up with the same type of analysis, but applies it on the image trimmed from noises and reconstructed.

The basic hypothesis is that the luminance intensity of the MTS body image depends, according to a quadratic relation, on the relative distance between the body and the sheet. This means that the radiative effect of the body decreases with the square of the distance.

An example of radiative energy is the emission of the heat for irradiation. In the hypothesis of black body (see figure 14) considering two elements of surface dA1 and dA2 oriented in any direction, placed at distance r and at the same temperature, the radiation power $q_{1\text{-}2}$ issued from surface 1 that reaches surface 2 depends on the intensity I, equal to:

$$dq_{1-2} = \left(I_{j\,1}\right)_n dA_1 \cos j_{\,1} \frac{dA_2 \cos j_{\,2}}{r^2} \qquad (1)$$

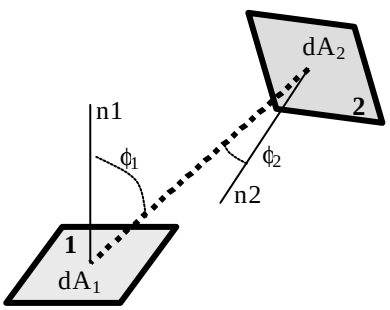


Figure 14: Diagram of the radiative energy emission.

where I_{j1} represents the intensity of emission of 1, and j_1 j_2 the angles formed from joining the two surface elements and respectively the normal to the element 1, n1, and the normal to the element 2, n2. It should be noted that the radiative power in the radiation follows a quadratic law of the distance between the two surfaces in question.

In the case under examination, the relation that can describe the phenomenon of the body image impression through a form of radiative energy is the following:

$$L = \frac{k}{d^2} \tag{2}$$

where L represents the luminance of the image in a single pixel, d is the distance of the emitting body from the TS in the considered point, while k is a dimensional constant that links the two variables.

According to the relation as defined, the relative distances between the body and the TS can be abstracted from the images to disposition according to the equation:

$$d = \sqrt{\frac{k}{L}} \tag{3}$$

Setting point D6 (L = 12) in correspondence with the abdomen as point of least luminance, and then maximum distance (see figure 15) and the maximum luminance at point C7 (L = 174), which coincides with the left knee, the following relation is obtained:

$$d = \frac{30.5}{\sqrt{L}} - 2.3 \text{ cm } \pm 0.5 \text{ cm} \tag{4}$$

4) EXPERIMENTAL DATA

The problem that must be solved is that of determining the geometric configuration of the enveloping and the outline of the MTS beginning with the body image of the TS, knowing that the luminance of the body image codifies an information of bsd (see figure 15).

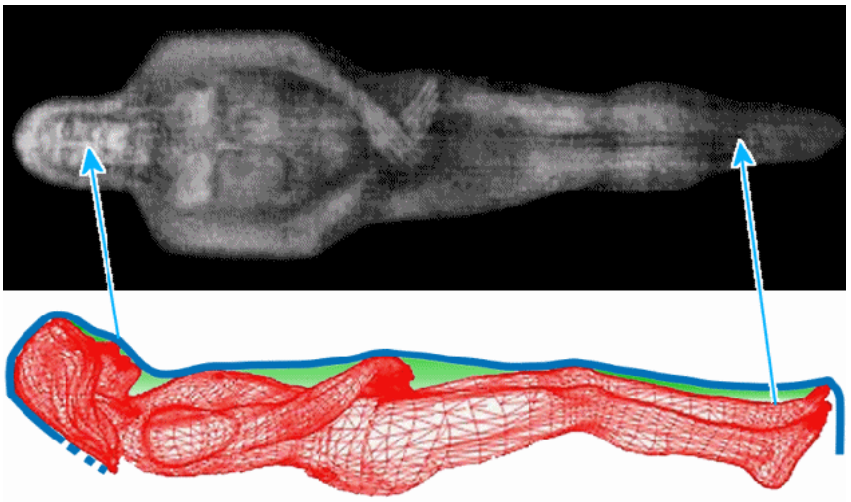


Figure 15: Starting from the information of the bsd codified in the body image, the idea is to determine the body enveloping.

In order to obtain data which the luminance values of the body image refer to, measurements were performed on a human body[30] in a similar position to that assumed by the MTS, recumbent on a surface and enveloped by a sheet 0.30 ± 0.05 mm thick.

The experimental distances between the body and the sheet were measured along the broken line given in figure 16 in correspondence to the red points, D code. The heights from the plane of reference are given in correspondence to the blue points, C code. The measured values are given in table1.

The points that shift more from the experimentally acquired values are those that correspond to the zone of the mouth and of the neck. For the point corresponding to the zone of the mouth it can be supposed that the bsd is less in comparison with that measured, because of the presence of diffuse blood that has not been completely eliminated during the phases of cleaning and might have altered the luminance levels. The zone of the neck (D3) might be due to a configuration of enveloping different from that hypothesized (for example a folding of the sheet around the chin); in this area, in fact, the values of distance shift more than one centimeter from those foreseen.

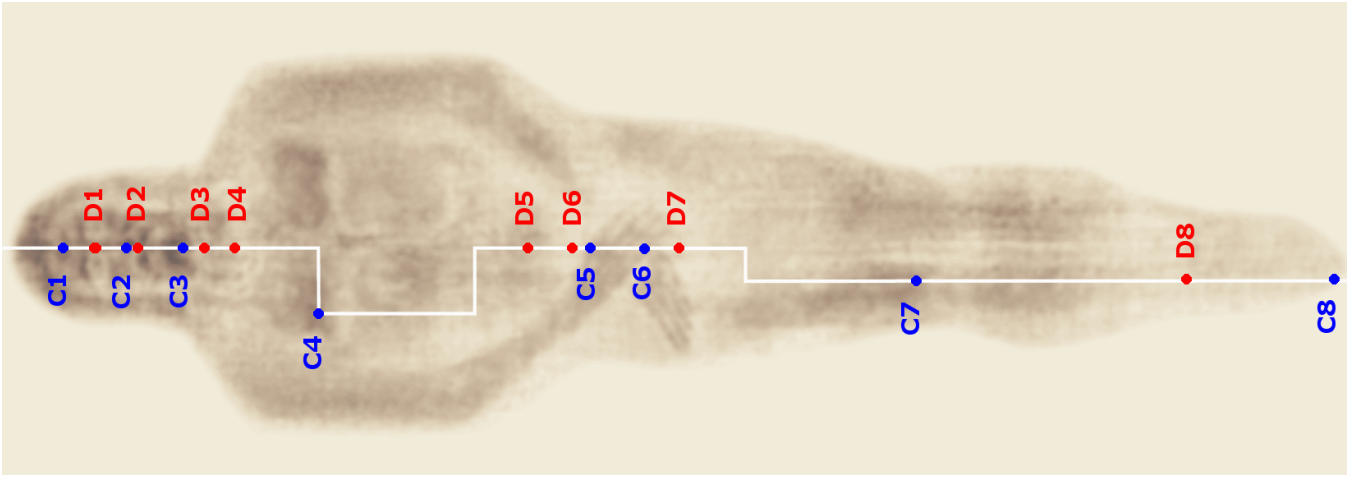


Figure 16: Diagram of the broken line along which the measurements were performed.

Table 1: Experimental measured values.

Point	Height from the reference plane (cm)	Luminance	Point	Body-sheet distance (cm)	Luminance	Calculated values (cm)
C1	25.6 ± 0.3	131	**D1**	1.3 ± 0.5	102	0,7± 0.5
C2	25.9 ± 0.3	150	**D2**	2 ± 0.5	123	0,5± 0.5
C3	22.5 ± 0.3	153	**D3**	3 ± 1	109	0,6± 0.5
C4	20.6 ± 0.3	106	**D4**	5 ± 1	23	4,0± 0.5
C5	27.4 ± 0.3	131	**D5**	3.5 ± 2	77	1,2± 0.5
C6	27.4 ± 0.3	131	**D6**	6.5 ± 1	12	6,5± 0.5
C7	27.8 ± 0.3	174	**D7**	10 ± 2	9	7,9± 0.5
C8	20.6 ± 0.3	-	**D8**	6 ± 2	22	4,2± 0.5

Subtracting the measured bsd values from the outline of the experimental sheet, one arrives at the definition of the experimental outline of the human model; the results are shown in the graph of figure17.

A sample consisting of 900 pieces of data of the luminance of the TS was then acquired along the broken line defined in figure 15; the values obtained are indicated in figure 18. The rather anomalous appearance of the outlines of luminance highlights that, despite the cleaning operation, some irregularity still exists, maybe also linked to the effect of the sheet weft.

Subtracting in the same way the values obtained from the relation (4)[31], the body outline of the MTS, given in figure 19, is obtained.

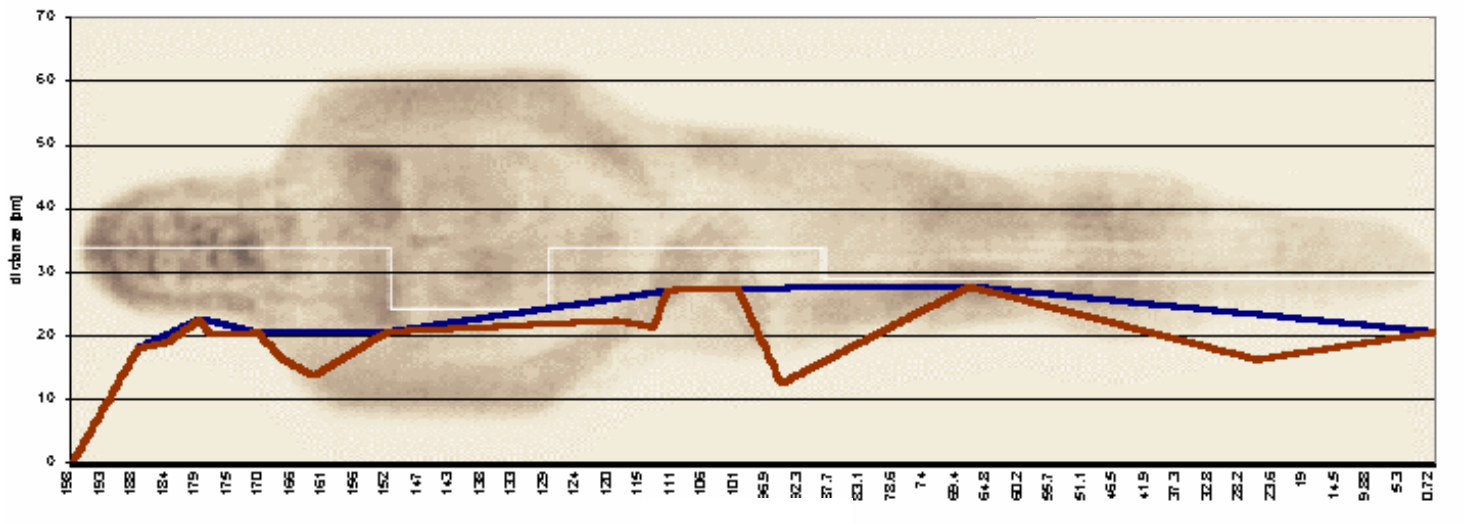


Figure 17: Outline of the experimental sheet and outline of the measured human body.

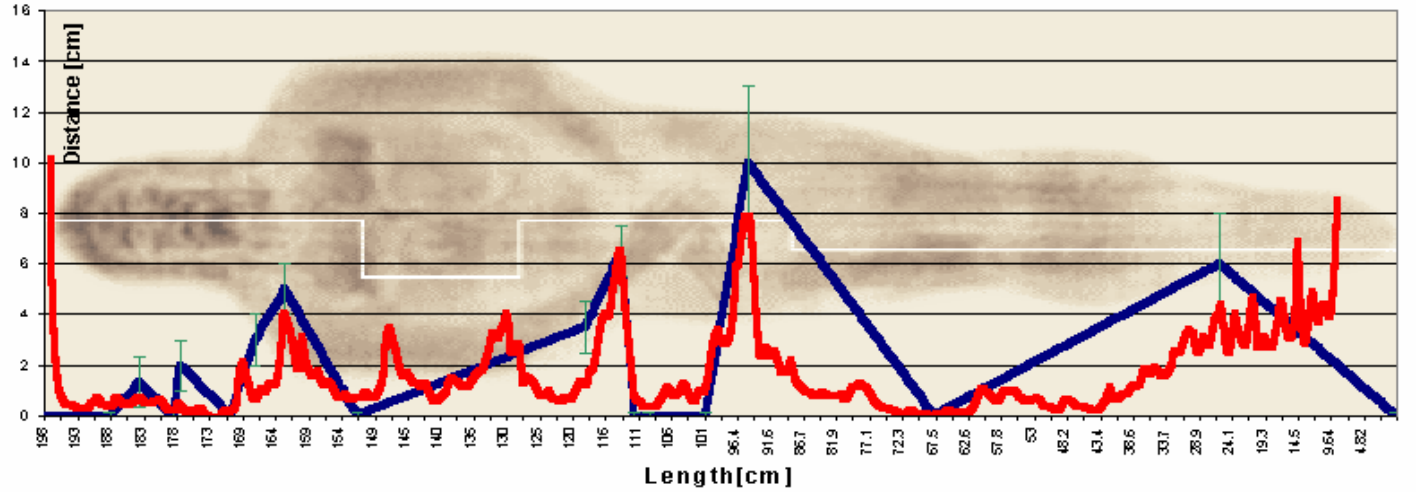


Figure 18: Values of the bsd drawn from the luminance of the frontal image along the outline characterized in figure16.

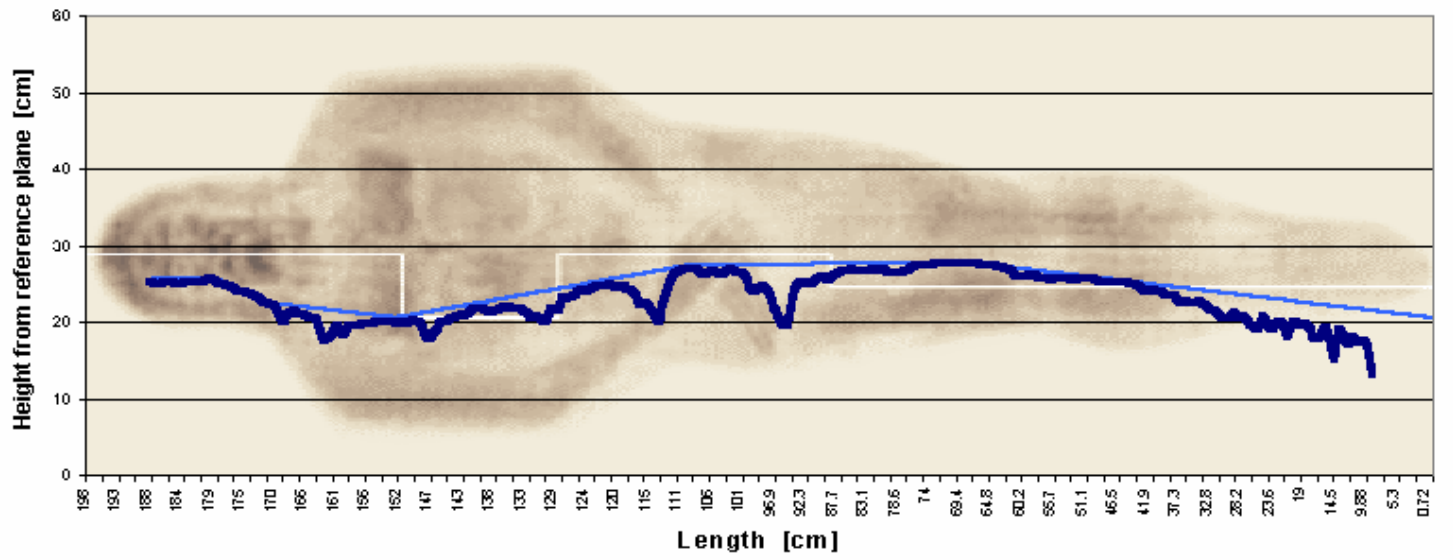


Figure 19: Outline of the experimental sheet and more probable outline of MTS calculated on the ground of the luminance values of the body image.

The results obtained confirm the hypothesis of a simple enveloping of the sheet around the MTS, without the existence of nooses or bandages that set the body in contact with the sheet in preferential zones.

5) DISCUSSION

From the analyses performed[32] it seems therefore that the best hypothesis of the enveloping of the MTS is the following. The flat surface, probably made of stone, was covered by mineral salts and aromas (for example traces of natron were found on the lower part of the TS) and a part of the TS was spread on it. Then the MTS was laid on it, impressing a mark on the surface of the support with salts, rendering it lightly hollow and enveloping. Plants and flowers were then settled around the MTS (some traces of flowers[33] and of their pollens[34] are evident) and finally the free part of the TS covered the Man and the flowers.

Maybe the different enveloping configuration of MTS-sheet happened during the impression of the traces of blood (this happened first[35]) and during the impression of the body image (which happened afterwards[36]), and was caused by a possible shifting of the geometric configuration taken on from plants and flowers set around the MTS.

In this work a square relation between bsd and luminance has been assumed, but it would be necessary for future studies to verify the real validity of this law that also implicates different mechanisms of formation of the body image. Recent studies[37] have highlighted that simple relations between bsd and luminance (see figure 20 A) are legitimate. In this hypothesis little areas of the surface of the TS emanate a collimated radiation, under the form of a thin vertical beam, toward the TS, which for example could be protonic or neutronic rays[38].

Other sources of energy, type UV rays around 200 nm, X rays, gamma rays or thermic energy, that emanate the radiation in different directions, generate a type of body image that does not have a simple square relationship. In fact a little area of the Shroud sheet is hit by radiations coming from different little areas of the human body (see figure 20 B); this implies that the image does not have, as it appears to, clean contours and that the bsd-luminance ratio is rather more complex. In the case of rather regular surfaces, software for the thermic radiation exists, capable of solving the problem, but in the case of the surface of the human body the analysis becomes more complex; future studies will go into the problem in more depth.

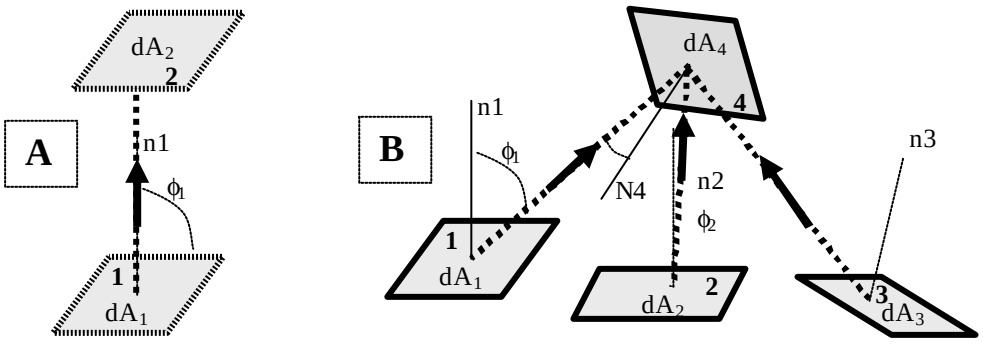


Figure 20: - A) simple relation of collimated radiations; - B) the more complex relation of diffuse radiation in different directions: the element of surface 4 of the TS receives components of radiations from the elements of surface of the human body 1, 2 and 3.

6) CONCLUSION

How was the MTS enveloped? This question may be partially answered by analyzing the three-dimensional characteristics encoded in the levels of luminance of the body image; these, in fact, furnish information on the distance enveloped body-sheet.

Unlike other analysis performed before, this study started after both the frontal and dorsal body images have been cleaned of all the noises that could interfere with the interpretation of the luminance levels, such as the traces of blood, water, fires, etc.. The body image has been also reconstructed in correspondence with the arms.

A digital computerized manikin, capable of being lengthened and moved, was then built. The dimensions and the position of the manikin were decided on the basis of both the anthropometric indices determined for the MTS and the compatibility determined in his enveloping with a digital sheet corresponding to the TS. The result was a man 175±2 cm tall, set in position compatible with that of a crucified man (except for the arms) with the feet extended (at 34° and 30° ± 2°), the legs partially flexed (angle of the knees 19.5° and 23.5° ± 3°) and the head flexed upwards (at 30° ± 4°).

In the body image formation hypothesis due to a burst of energy, a square relation was defined that links the intensity of the radiation, and then of the luminance of the body image, to the body-sheet distance.

Experimental tests were performed to determine the distance from a surface of support of a human lying body and these served to characterize the outline, along a broken line, of the MTS.

The outline of the MTS as defined is globally probable, even if some zones are to be studied in more detail, among which is that of the neck, where an anomaly of the outline has been seen, maybe caused by a fold of the sheet.

The best hypothesis for the enveloping of the MTS seems to be the following: the flat surface was covered with mineral salts and aromas; a part of the TS was spread on it; above it, the MTS was laid, rendering the plane enveloping, plants and flowers were then settled around the MTS and finally the free part of the TS covered the Man and the flowers. Maybe the different configuration of MTS-sheet enveloping happened during the impression of the traces of blood and during the impression of the body image, being caused by a shift of the plants and flowers set around the MTS.

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