Reprinted from IEEE 1982 PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON CYBERNETICS AND SOCIETY. October 1982

EXAMINATION OF THE TURIN SHROUD FOR IMAGE DISTORTIONS

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ABSTRACT

The main thrust of this study was to determine if any abnormalities (distortions) of the image on the Turin Shroud could be ascertained. An experiment was established to determine a comparative standard. The experiment identifies significant distortions which cannot be explained by anatomical variation or cloth stretching. The measurements appear to be consistent with a cloth draped over a three dimensional body form. Furthermore, image features support a vertical mapping process.

INTRODUCTION

The cloth known as "The Shroud of Turin" is well documented in the literature (1). There is a growing controversy over whether the image on the cloth was the work of an artist or the result of some natural process (2). None of these hypotheses have been demonstrated--which probably accounts for the controversy. Figure 1 shows the frontal image on the Shroud which appears to be a good resolution image of a male form. Though this image appears to be anatomically reasonable, there are some second-order characteristics which indicate that this may not be so: broadening of hips, elongation of arms and fingers, lateral displacement of hair away from side of face. Such distortions have also been noted by other investigators, for example Zugibe (3), who interprets them as Marfan's Syndrome, a hereditary disorder causing elongation of limbs. Our concern, however, is with image formation hypotheses which might account for various aspects of the image, both chemical and with respect to image structure. We therefore thought it appropriate to quantify possible image distortion on the Shroud to see if they are of a magnitude which cannot be explained by standard anatomical variation, thereby specifying some special conditions which an image formation hypothesis must explain.

EXPERIMENT

Our experiment began by selecting a group of male subjects (98) whose heights were 5'10" ± 2.0 inches. This height range was determined by placing subjects of various heights in a cloth model containing an image of the Shroud and determining for what heights correspondence with the image occurred. The cloth model used in our experiment was made of 345 ± 22 micron thick linen which well approximated the 325 micron thickness of the Shroud (4) and therefore, presumably, its draping characteristics when new. The drawn-in image was scaled according to measurements made by one author directly on the Shroud in Turin.

After ensuring each subject was generally arranged in the correct position, by aligning apparent points of contact, the cloth was removed and a photograph of the contorted person was taken from directly above. A grid system under each subject ensured no noticeable lens distortion. It was also interesting to note the apparent physical differences between each subject and the actual Shroud image. There were apparent differences between hip width, arm length, and finger length; all these physical features appear to be abnormal on the Shourd (Figure 1).

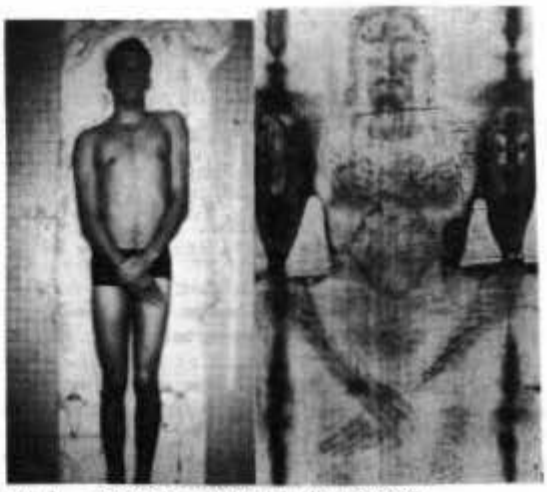

Figure 1. Frontal Image of the Shroud.

All 98 photographs were examined to eliminate any subject who had moved from the indicated position because alignment along the head to foot (height) axis was critical in establishing a reference axis which could be compared to width measurements. After collecting the sample

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population photographs that aligned in the vertical (50), teams measured and recorded the distances between selected body points. These measurements and their results are given in Figure 2.

A 9.86 ± .86 Middle (second) finger bottom hand, tip to web between adjoining fingers.
B 36.3 ± 1.6 Width of hips along horizontal level at "V" intersection of hands.
C 36.3 ± 1.5 Width of hips along horizontal level at bottom hand, tip of pointing (first) finger.
D 33.6 ± 1.8 Width of hips at Man of Shroud's right forearm intersection with body to left forearm intersection with body.
E 120 ± 2.8 Tip of nose to top center of Man of Shroud's left knee.
F 86.9 ± 3.0 Left nipple to top center of left knee.
G 22.5 ± 3.1 Width of knees, horizontal, exterior boundary to exterior boundary.
H 11.8 ± 1.9 Width of knees, horizontal, center to center.
I 13.9 ± .78 Width of face at hair/face intersections a long horizontal level through center of eyebrows.
J 12.6 ± 1.4 Width of face at bone structure at edges of eye sockets.
K 47.9 ± 2.1 Length of Man of Shroud's right forearm, elbow to tip of middle (second) finger.
L 42.5 ± 2.9 Breast bone at level of nipples down to knuckle of middle (second) finger of top hand.
M 33.9 ± 1.5 Inner elbow horizontally to inner elbow.
N 9.37 ± .59 Width of Man of Shroud's left (top) hand along ridge of knuckles.
O 32.2 ± 1.2 Width of arms (interior to interior) along horizontal line connecting nipples.
P 33.8 ± 2.4 Nose to breatbone at level of nipples.
Q 133 ± 2.5 Top of head (center) to tip of left knee (center).
R 22.5 ± 1.4 Nipple to nipple distance.
S 8.93 ± 1.4 Length of ring (third) finger, web between adjoining fingers to tip, top hand.
T 9.38 ± .98 Length of ring (third) finger, web between adjoining fingers to tip, bottom hand.
U 9.84 ± .85 Width of Man of Shroud's right (bottom) hand along lower base of top hand.
V 68.6 ± 2.9 Man of Shroud's right elbow (exterior) to his left knee.
W 71.6 ± 3.1 Man of Shroud's inner elbow of left arm to his left knee.

Figure 2. Average Measurements from the Selected Population (centimeters).

As a check, we compared our sample measurements with documented 1967 anthropometric data of a fully grown, male adult, 5'10" (5). Several of the anthropometric measurements were of the same body parameters as the measurements in our sample population; a comparison is listed in Figure 3. These measurements are in good agreement, which support our measuring technique.

	APSC	Sample
Hand Breadth	8.92	9.37 ± .59
Middle of Eyes to crotch	79.2	81.3 ± 3.7
Hip Breadth	38.0	36.3 ± 1.6
Right Forearm to tip of Finger	46.5	47.9 ± 2.1
Middle Finger	9.80	9.86 ± .86
Face Breadth	14.3	14.0 ± .78

Figure 3. Comparative Measurements (centimeters).

The photograph used to determine Shroud body measurements was a 1931 photograph taken by Enrie (6). This photograph was chosen because it seemed to well define limits of the body image. Since our experiment involved measuring image distortions, we had to ensure that cloth stretching and camera distortions were sufficiently small. We evaluated both potential sources of distortion by projecting Miller's 1978 negative image of the Shroud over Enrie's 1931 positive print. The correspondence between these images was remarkably close, but we estimated differences $\Delta\ell/\ell \leq 0.4\%$ for a length ℓ on the image. Thus, we concluded that cloth-stretch distortions are probably no greater than this value since these two photographs represent two independent occassions of exposition. We estimated photographic distortion from Miller's 1978 photograph, realizing that these results also apply to Enrie's 1931 photograph, to an accuracy of 0.4%. This was possible because Miller's photograph was a series of three adjacent photographs and slight discrepancies in overlap could be measured. We estimated for photographic distortions, $\Delta\ell/\ell \leq .7\%$. Measurements of the Shroud image were taken and are given in Figure 4. Because of damage to the actual image on the Shroud, some had to be estimated. In particular, the elbow region of the Man of the Shroud's lower forearm has been burned away, thereby hindering accurate measurement of the forearm length. However, we assumed that the elbow was at the burn mark intersection although it could have been further in. This assumption was also consistent with where the "blood" flow departs from the forearm, probably indicating where the elbow should be located. In this way we were generally conservative in our measurements.

A (2.7) 12.2	I 15.0	Q 133.2
B (2.5) 40.4	J 13.4	R 22.8
C (1.9) 39.2	K (2.7) 53.7	S 9.07
D (7.8) 47.7	L 44.7	T 11.1
E 117	M (2.2) 37.4	U 8.66
F 88.8	N 8.29	V (2.1) 74.6
G 23.4	O 33.7	W 71.1
H 11.9	P 30.3	

Figure 4. Shroud Measurements (centimeters).

In Figure 4, we indicate which Shroud measurements fall about ± two standard deviations or greater of the mean for that measurement (as indicated in Figure 3) by a number (in parenthesis) giving the number of standard deviations. Thus, the number of measurements displaying a distortion "signal" against a background of anatomical "noise" is seven. For the remaining 16 data points, the signal to noise ratio is too small for meaningful conclusions. It is important to note that the noise is due to a fundamental uncertainty as to the exact dimensions of the body shape which should be associated with the Shroud image, and accordingly we had to represent that shape by a

statistical ensemble of volunteer subjects. It is noteworthy that all measurements falling outside two standard deviations (i.e., hip width, finger length, bottom arms length) are longer than the mean values and that they can be seen by comparing a typical, subject photograph with the Shroud image in Figure 1.

We considered these seven measurements, some of which are several standard deviations from the mean, as definite indications that statistically significant distortions exist in the Shroud image. These data, however, are probably insufficiant to discriminate between various hypothesis which might attempt to explain the distortions. However, in the Interpretation Section, we propose an explanation of these distortions.

INTERPRETATION

The general layout of the Shroud image suggests that it was formed by the Shroud draping over a body; thus, it is natural to propose that the image distortions might be due to cloth drape. In other words, we are suggesting possible image distortions caused by projecting a three dimensional object onto a curved cloth drape, then observing the cloth flattened onto a two dimensional surface. In Figure 5, we show an image made from projecting a body photograph onto a curved surface modeling a draping cloth over a body. This surface was generated from biostereometric data of a cloth model of the Shroud draping over a volunteer subject whose undistorted image is also shown in Figure 5 (7). Although somewhat exaggerated, it does point out areas where expected distortions should occur on the Shroud image, if the Shroud cloth covered a human body form when the image formed. We note that the hips, forearm, and fingers (if they had been extended) would show positive distortion as indicated by the data of Figure 4. We further note that other distortions such as broadening of the hair can be observed in the Shroud image.

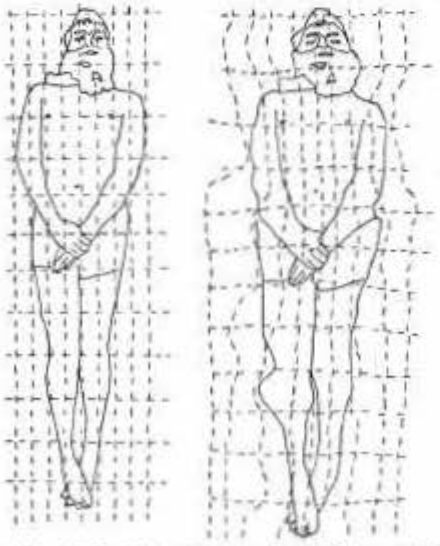

Figure 5. Body Distortions Caused by a Cloth Drape.

The face does not appear to be distorted, however, but careful analysis does indicate that geometric distortions probably exist. At the edges of the face on both sides we note in Figure 6 that the image is sharply truncated. These regions occur at precisely the place where the herringbone weave pattern of the Shroud changes direction; hence the truncation is probably an artifact of the cloth and not of the image itself. Further, there is a blood image on the right of the face and forehead level indicating that a supportive structure for this blood could have been present in the region where apparently no image was formed. Most likely, this would be the continuation of the face into that region. Most suggestive of all is a faint image which seems to be a continuation of the face extending into the void up to the hair (note in particular the extension and distortion of the eye sockets). Comparing this image with Figure 5, shows that the facial image on the Shroud could be distorted in accordance with the draping characteristics of a cloth over a face. On the Shroud, the hair seems to hang abnormally off to each side of the face, but what could have happened is that the hair was actually in contact with the sides of the face but displaced away by geometric distortion.

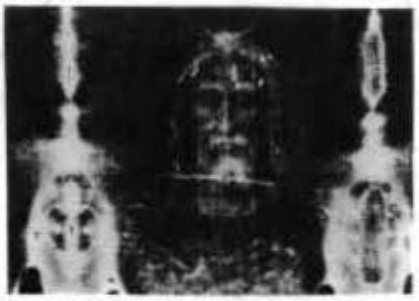

Figure 6. Shroud Facial Features (8).

It is important to point out that Figure 5 imagery should be regarded as general indications of where cloth-drape distortions ought to occur and not necessarily as an indicator of distortion magnitude, for in the case of the Shroud, precise boundaries are nonexistent where on Figure 5 they are well defined. Accordingly, the Figure 5 image probably appears more distorted than on the Shroud.

Thus, we feel the interpretation of image distortion on the Shroud due to cloth-drape is reasonable. This is not to say, however, that a cloth draped over a body at the time of image formation because it might be possible to interpret the image distortions in some other way. Zugibe's (3) explanation noted above, however, is probably premature because it presupposes a body under a cloth and distortions due to Marfan's syndrome would have to be considered only after taking into account cloth-drape distortions. Logically, image distortions should be viewed as an image characteristic to be explained by a particular hypothesis and we only note here that detectable image distortions are consistent with those induced by cloth drape. We discuss the relation of various hypothesis to image distortions in a separate paper (9).

We should point out that the notion of cloth-drape distortion is to some extent ambiguous because the character of such distortions depends upon how body features are presumed to have been mapped onto cloth. This is illustrated in Figure 7 which shows three paths information could have taken in order to reach the cloth. It is conceivable that body surface information might have been mapped along normal paths to the body surface, or normal paths to the cloth surface, or perhaps even along parallel, vertical paths between the two surfaces. As illustrated in Figure 7, which shows the cross-section of the nose and cheeks, each mapping process would obviously produce images of different distortion when the Shroud is laid flat.

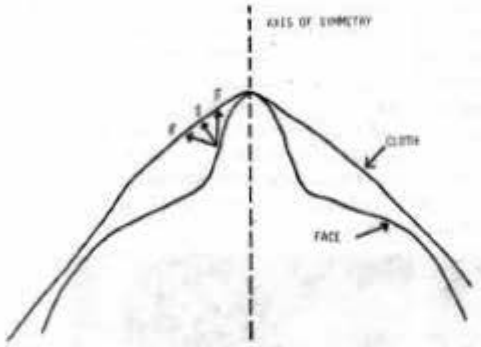

Figure 7. Possible Paths from Body to Cloth.

Above the body and cloth profiles, shown in Figure 8, is a microdensitometer plot of the Shroud image to scale at the nose. From this drawing, it is apparent that only mapping in a vertical direction produces nearly correct correspondence between points on the body and cloth. Projections normal to either the body or cloth surfaces would produce an image with significantly greater distortions. In fact, projection normal to the body surface would produce a region of "confusion" between the side of the nose and cheek. From this simple procedure, it would appear that a vertical mapping from the body to cloth would best explain the type of distortion which might be attributable to cloth-drape.

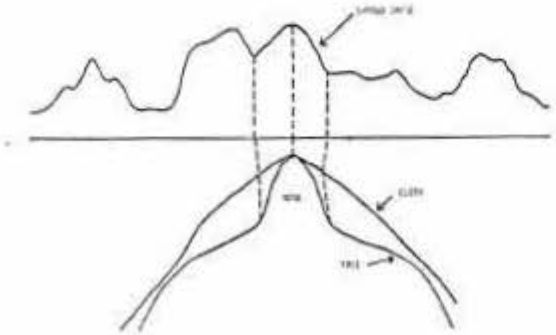

Figure 8. Microdensitometer Trace of Shroud Face Compared to Cloth Drape.

It is noteworthy that a vertical mapping would explain several subtle features of the Shroud image. One characteristic is the lack of side images anywhere on the frontal image. And second, the apparent "blanking" of the image in the vicinity around the hands would be explained. In particular, the image of the bottom hand at the lower level intersection with the top hand is "blanked out" for about a finger's width. A simple explanation is that the cloth tucked about the top hand and where the cloth was essentially vertical, no image was transferred even though the cloth was apparently close enough for image formation to occur (i.e., the top and bottom hands are visible). If the mapping was normal to either the body or cloth surfaces, an image should have been formed, but if vertical, no image would have been generated until the cloth "leveled" out over the bottom hand. Such characteristics are compatible with a vertical mapping/cloth-drape interpretation of image distortions which have been demonstrated above to exist on the Shroud image.

CONCLUSIONS

In conclusion, we note the following:

1. The Shroud image contains significant distortions which cannot be explained by anatomical variation, cloth stretching, or photographic perturbation.

2. These distortions seem to be consistent with those induced by a draping cloth over a full three dimensional body form.

3. If conclusion two is physically valid, then the character of the distortions and some anamolies of the image seem to be best explained by a vertical mapping process.

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