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Construction of a quantitative image of Turin Shroud for details recognition

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Abstract

In 1978 measurement of x, y, z CIE color values were made for the first time on many small areas of the Turin Shroud; also quantitative photographs were made in 1978 on features but up to now no quantitative image of the whole Shroud is available. For this reason after the conversion of color space and the correction of single color channels, basing on a photograph of G. Durante realized in 2002, a quantitative photograph of the whole Shroud was obtained. The measurement of colors on this quantitative image, that has an uncertain of 4%, with a reference database, allow to recognize and distinguish various interesting TS features.

Keyword: quantitative image, characteristics recognition, color measurement, Turin Shroud.

1. INTRODUCTION

Even if many different studies on the TS (Turin Shroud) have been performed [1], up to now it was not available a quantitative photograph of the whole TS to which made reference in color measurements or in the analysis of small characteristics like the differentiation of different types of human blood.

In 1978, measurements of x, y, z CIE color values were made for the first time on small areas of the Turin Shroud [2]. Also quantitative photographs were made in 1978 by D. Devan & V. Miller [3] on parts of the TS. For this reason, starting from the photograph of G. Durante realized in 2002, a quantitative photograph of the whole Shroud was obtained after a proper calibration of the RGB values using colorimetric data of selected small areas of the TS. The used procedure was calibrated in order not to exceed an uncertainty of 4%.

2. METHOD

This study is primarily oriented to construct a quantitative image of the TS starting from a photo realized in 2002 by G. Durante using a Fuji Provia 100 ASA film, printed and successively digitalized by a scanner.

Color information of the digital photo, was converted [4, 5, 6] from sRGB color space into XYZ CIE color space to build the quantitative image. That transformation was operated because the data reported in Ref [2] were expressed in CIE XYZ color space coordinates. The obtained x, y, z chromatic coordinates were used for comparison with colorimetric data [2], acquired in 1978 on the TS by a colorimeter and CIE XYZ color space was also used for a database construction. Many measurement points were acquired on the TS, but only 18, were selected for calibration.

To perform the color measurement, histogram function of a common photographic software, see Figure 1, was used to have the 3-channel average of an image area.

After correction and calibration of the TS photograph a color measurement was performed in order to build a x,y,z CIE database of the main TS characteristics like cloth, blood, image, water spot and burnings.

A total of 1188 measurements in different spots of the TS image were performed and the color relationships x/z and x/y were reported in a plot, useful for measurement comparison of unknown or not clear characteristics.

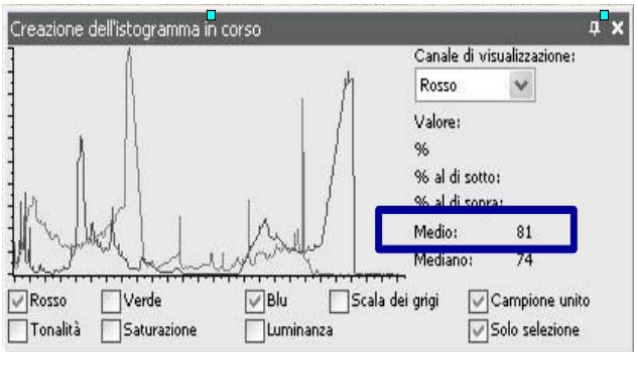

Figure 1. Histogram function of Jash Paint Shop Pro© software used to determine the average values of the region of interest.

3. CALIBRATION PROCESS

The image calibration phases are reported in the following steps:

1. Acquisition of RGB values from photographic image

(2002 G. Durante).
2. Conversion of color space from sRGB to XYZ CIE and to xyz and conversion of the illuminant D55 to A.
3. Comparison of digital measurements with colorimetric data [2] to determine the calibration function.
4. Correction of colorimetric xyz coordinates
5. Application of the correction to the TS photo of Step 1.

Correction operation can be summarized by the scheme shown in Figure 2.

The measurements were performed by using the same circular area of 13 mm in diameter, utilized in Ref. [2].

In reference to the TS photo of Step 1 which has pixel sizes of 0.19 mm/pixel, the diameter of circular digital area selector was of 68 pixel.

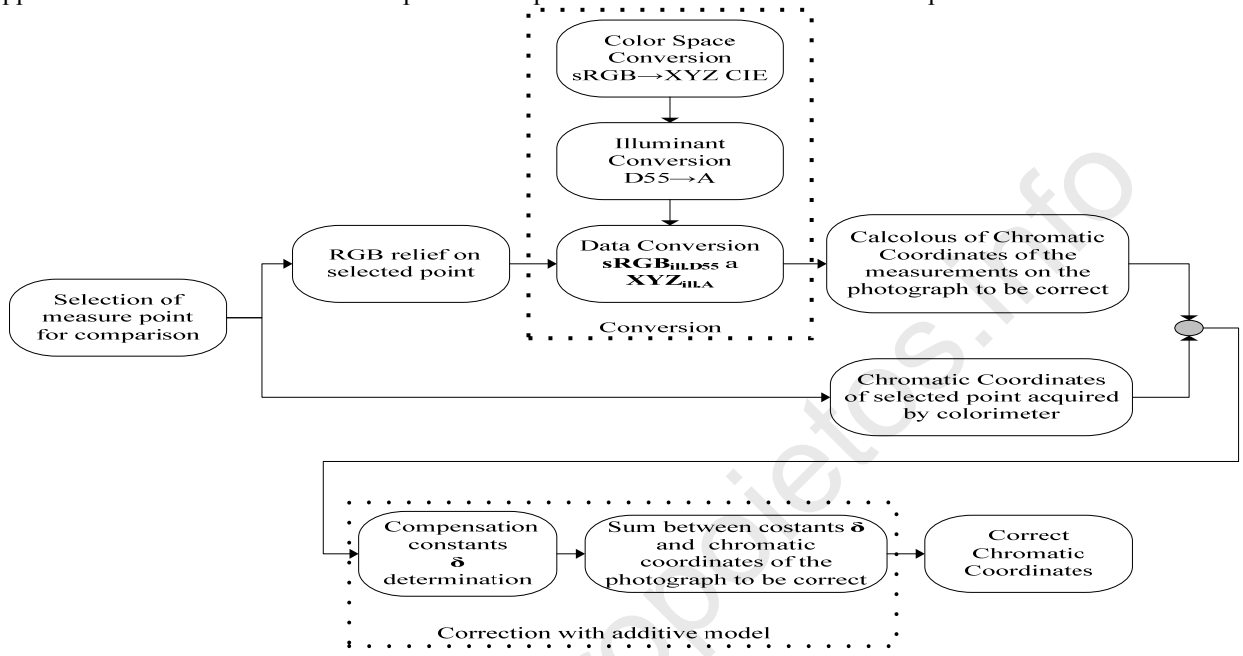

Figure 2. Flow chart of the calibration procedure to build a quantitative image of the TS.

With indication contained in Ref. [2], considering the problem relative to the definition of the reference areas, 18 points were selected on the basis of the smaller position uncertainty.

The RGB values acquired in these points were converted to XYZ CIE color system using the matrix operation of Eq. (1):

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_A = [T] * \begin{pmatrix} R \\ G \\ B \end{pmatrix}_{D55} \qquad (1)$$

Where:

$$[T] = \begin{bmatrix} Bradford \\ Matrix \\ D55 \rightarrow A \end{bmatrix} * \begin{bmatrix} Transform \\ sRGB \rightarrow XYZ \\ Matrix \end{bmatrix} \qquad (2)$$

and:

$$sRGB \rightarrow XYZ = \begin{pmatrix} 0.4125 & 0.3576 & 0.1804 \\ 0.2127 & 0.7152 & 0.0722 \\ 0.0193 & 0.1192 & 0.9503 \end{pmatrix} \qquad (3)$$

$$D55 \rightarrow A = \begin{pmatrix} 1.1803 & 0.0969 & -0.1386 \\ 0.1334 & 0.9183 & -0.0499 \\ -0.0217 & 0.0327 & 0.3732 \end{pmatrix} \qquad (4)$$

Applying Eqs. (3) and (4), the T matrix becomes:

$$T = \begin{pmatrix} 0.5049 & 0.4748 & 0.0882 \\ 0.2494 & 0.6985 & 0.0429 \\ 0.0052 & 0.0601 & 0.3531 \end{pmatrix} \qquad (5)$$

Using the previous relationship, after obtaining the XYZ value with A illuminant, it's possible to calculate the xyz chromatic coordinates using Eq. (6):

$$x = \frac{X}{X+Y+Z} \quad y = \frac{Y}{X+Y+Z} \quad z = \frac{Z}{X+Y+Z} \qquad (6)$$

Calibration made by comparison between data measured by colorimeter [2] and those calculated from RGB values of the photo of Step 1, allowed to determine three compensation constants δ_x, δ_y, δ_z for the to x, y, and z values. These values were calculated for each color channel basing on the mean value resulting from the 18 calibration points.

The differences between the mean values of the 18 calibration points reported in Ref. [2] with the data calculated above, gives the following compensation values:

$$\delta_x = 0,026 \quad \delta_y = 0,016 \quad \delta_z = -0,042$$

4. QUANTITATIVE IMAGE CONSTRUCTION

Using the analyzed color space transformation and the compensation constraints it's possible to build the quantitative photograph of the TS.

Every digital image is represented by a tridimensional matrix formed by a "sandwich" of 3 layer (R, G, B) of $m \times n$ matrix (where m is the number of horizontal pixels and n is the number of vertical pixels of the analyzed image), so by loading the digital photo in a mathematical software, it's possible to transform and to compensate each pixel for every color channel to get a quantitative image in XYZ CIE or sRGB color space. As an example, the results for the face of the TS Man are reported in Figure 3.

The resulting uncertainty at 95% confidence level of the quantitative image is ± 4%. This value was obtained by using the square root sum of the square power of the single relevant uncertainties.

It was considered. –a) the uncertainty of the G. Durante's photograph, mainly due to the non uniform illumination of TS (±2.5%); -b) the uncertainty connected to the transformation matrix (±0.5%); -c) the uncertainty of calibration correction (±2.0%); -d) the uncertainty of the reference value (±1.5%).

Figure 3. Example of correction of the TS face. From left to right: original photographic image, corrected image represented in XYZ CIE color space, quantitative image represented in RGB color space.

5. COLORIMETRIC DATABASE

After the procedure of color correction, a database of chromatic coordinates was built to define the color characteristics of cloth, body image, bloodstains, water and burns,. With this database it is possible to compare colorimetric data to classify unknown details present in the body image such as small spots, stains and segments.

Before to construct the database, a smaller measurement selector was determined to reach a better adaptability on small features. The spot was optimized in shape and dimensions, after the comparison of the stability to color measurements obtained on various TS reference areas; a circular spot selector with a diameter of 12 pixels (equivalent to 2.3 mm) was selected. For example, Figure 4 reports two different shapes of the color measurement areas, applied on the "reversed 3" bloodstain: the circular selector results the best fit.

To obtain the mean RGB values, the same procedure based on the average provided by the histogram function was used.

The data, relative to color measurements, were reported in the x/y and x/z chromatic coordinates ratios; then the values obtained can be plotted to show the chromatic characteristics of each feature and to classify it.. As an example the plot relative to the bloodstain measurements is reported in Figure 5. Two data clusters are evident: area A contains the values referred to scourge marks, and area B contains the values referred to draining blood marks. Obviously the same operation can be made for the other features examined in the database construction.

For the database use, consider for example the additional draining blood marks reported in Figure 6 that were not used for the database construction. The chromaticity data of these five points are reported in Table 1. By comparison of these data with the bloodstains database plotted in Figure 5, it can be seen (star points) that this characteristic falls in the area B confirming that these bloodstains coming from the image of the wrist are really draining blood marks.

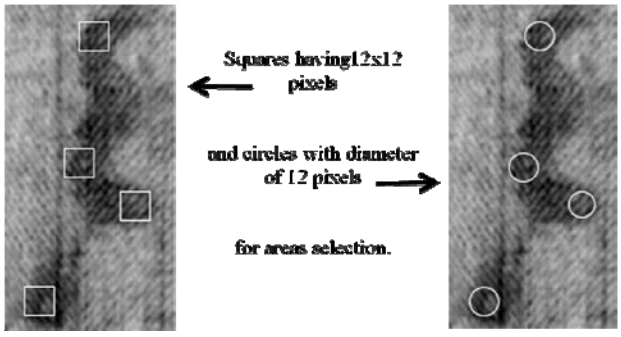

Figure 4. Different shapes of area selector in the color measurement of the "reversed 3" bloodstain.

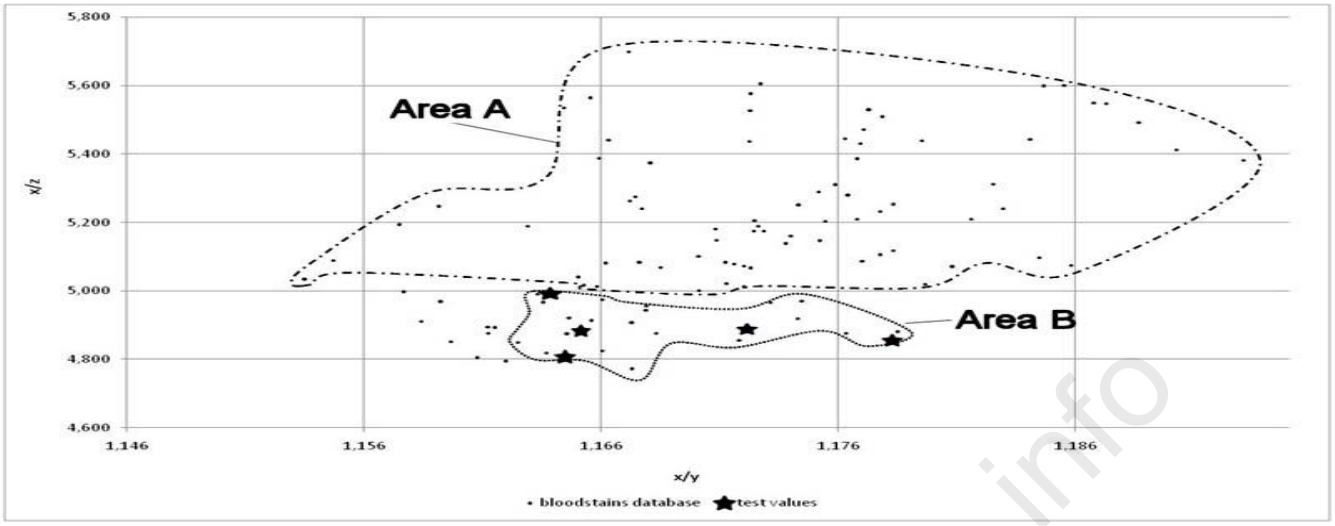

Figure 5. Plot of chromatic coordinates ratio (x/y and x/z) relative to bloodstains characteristics area. There are also indicated the test point in reference to figure 6 and table 1.

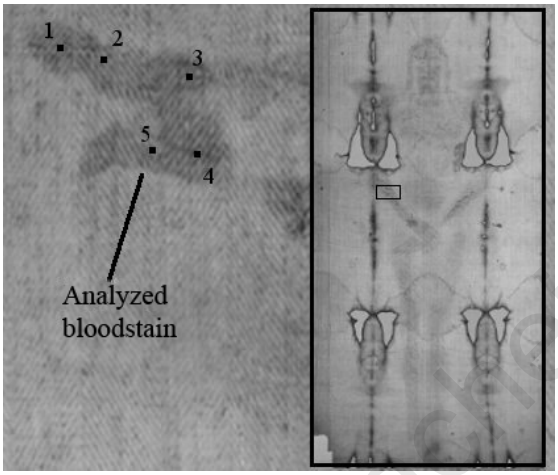

Figure 6. Measurement points on a draining blood mark used for test.

TABLE 1. Colorimetric data acquired in reference fig.6.

Ref.	x	y	z	x/y	x/z	y/z
1	0,485	0,416	0,099	1,165	4,890	4,197
2	0,486	0,415	0,099	1,172	4,891	4,172
2	0,486	0,418	0,097	1,164	4,996	4,293
4	0,487	0,413	0,100	1,178	4,857	4,122
5	0,484	0,416	0,101	1,164	4,801	4,124

With this method it is possible to classify unknown details by a simple chromaticity measurement on the quantitative body image of the TS and comparison with database values.

In the following figures and tables the color measurements relative to some characteristics area are reported:

- Figures 7 and 8, and Tables 2 and 3: body image;
- Figures 9 and 10 and Tables 4 and 5: bloodstains;
- Figure 11 and Table 6: cloth (front side);
- Figure 12 and Table 7: water stains of TS (front side).

For page limitation, other figures and tables are not reported but the authors are planning to put them in the first author's website.

6. CONCLUSION

This study allowed to correct a digital image of the TS with an uncertainty of ± 4 % basing on some photometric data. An additive model was used for correction of chromaticity coordinates, obtaining the first quantitative whole image of the TS.

The quantitative image allows to make color measurements of TS details such as body image, bloodstains, cloth, water stains and burns.

The recognition of details on the TS image has been successfully tested using areas of both bloodstains and body image areas not used during calibration; in the paper an example of bloodstains is presented.

With the resulting quantitative photograph of the TS it is possible now to measure and compare various details from a colorimetric point of view giving the possibility to perform new investigations, without the necessity to be physically in front the most important Relic of Christianity.

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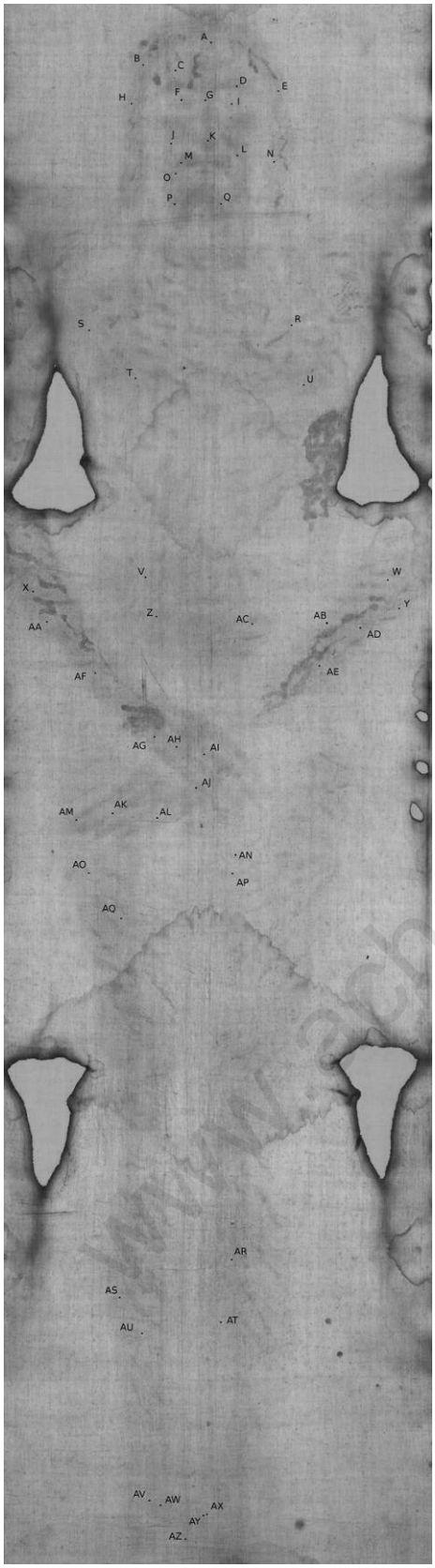

Figure 7. Image colorimetric data acquisition point in front side.

TABLE 2. Colorimetric data acquired in reference to fig.6.

Ref.	x	y	z	x/y	x/z	y/z
A	0,481	0,421	0,099	1,143	4,868	4,260
B	0,478	0,421	0,101	1,136	4,720	4,157
C	0,479	0,421	0,101	1,136	4,741	4,173
D	0,485	0,423	0,093	1,146	5,227	4,562
E	0,476	0,421	0,105	1,130	4,549	4,024
F	0,478	0,422	0,101	1,135	4,732	4,171
G	0,479	0,421	0,102	1,137	4,708	4,139
H	0,478	0,421	0,102	1,134	4,663	4,111
I	0,479	0,422	0,100	1,134	4,803	4,237
J	0,479	0,422	0,100	1,135	4,785	4,217
K	0,486	0,422	0,093	1,151	5,252	4,563
L	0,478	0,423	0,100	1,132	4,779	4,221
M	0,484	0,422	0,095	1,146	5,104	4,452
N	0,478	0,422	0,102	1,133	4,707	4,155
O	0,481	0,422	0,098	1,142	4,907	4,298
P	0,486	0,423	0,093	1,149	5,246	4,566
Q	0,485	0,422	0,094	1,149	5,183	4,512
R	0,477	0,422	0,102	1,132	4,687	4,139
S	0,478	0,422	0,101	1,134	4,754	4,193
T	0,476	0,421	0,104	1,130	4,580	4,052
U	0,478	0,422	0,101	1,132	4,726	4,174
V	0,477	0,423	0,101	1,127	4,703	4,172
W	0,477	0,421	0,104	1,134	4,604	4,061
X	0,478	0,421	0,102	1,137	4,675	4,111
Y	0,477	0,421	0,103	1,132	4,616	4,078
Z	0,481	0,422	0,098	1,141	4,925	4,316
AA	0,480	0,422	0,099	1,138	4,826	4,241
AB	0,477	0,421	0,103	1,131	4,644	4,105
AC	0,477	0,421	0,103	1,131	4,628	4,092
AD	0,477	0,422	0,103	1,130	4,641	4,106
AE	0,478	0,421	0,102	1,133	4,684	4,133
AF	0,478	0,422	0,101	1,135	4,742	4,179
AG	0,478	0,422	0,100	1,133	4,765	4,206
AH	0,481	0,422	0,098	1,141	4,888	4,284
AI	0,480	0,421	0,100	1,138	4,809	4,224
AJ	0,480	0,422	0,099	1,138	4,833	4,248
AK	0,478	0,422	0,101	1,135	4,742	4,179
AL	0,479	0,423	0,099	1,134	4,821	4,251
AM	0,480	0,421	0,100	1,139	4,779	4,195
AN	0,477	0,422	0,102	1,131	4,692	4,147
AO	0,478	0,421	0,102	1,134	4,666	4,114
AP	0,475	0,421	0,105	1,129	4,526	4,010
AQ	0,480	0,422	0,098	1,139	4,879	4,285
AR	0,479	0,422	0,100	1,133	4,785	4,222
AS	0,479	0,422	0,100	1,135	4,785	4,217
AT	0,478	0,422	0,101	1,134	4,743	4,185
AU	0,479	0,423	0,100	1,132	4,806	4,247
AV	0,476	0,421	0,105	1,131	4,550	4,023
AW	0,478	0,421	0,102	1,135	4,666	4,112
AX	0,477	0,421	0,103	1,134	4,623	4,077
AY	0,477	0,421	0,103	1,131	4,627	4,090
AZ	0,478	0,422	0,102	1,133	4,699	4,147

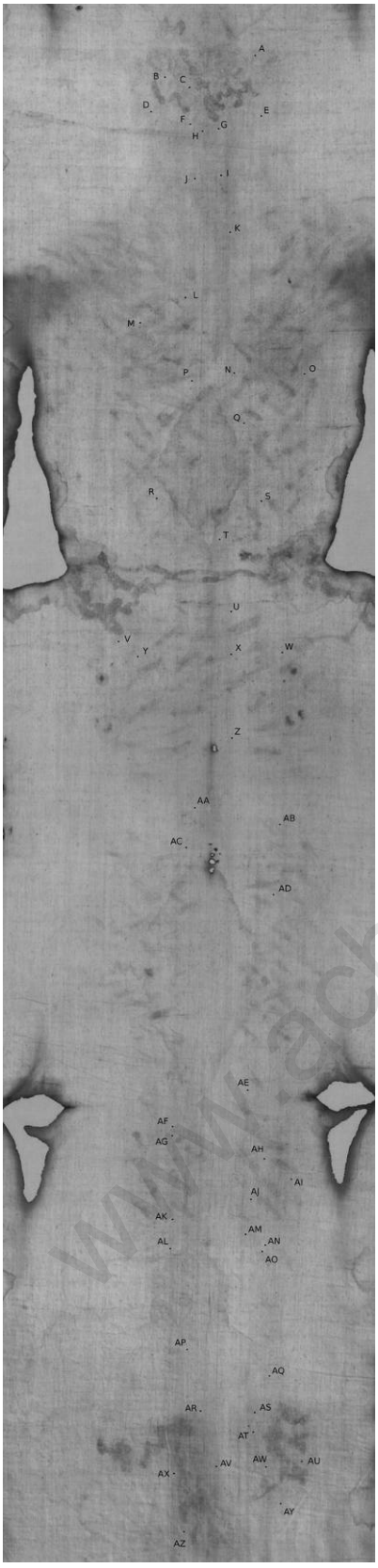

Figure 8. Image colorimetric data acquisition point in back side.

TABLE 3. Colorimetric data acquired in reference to fig.7.

Ref.	x	y	z	x/y	x/z	y/z
A	0,482	0,421	0,098	1,143	4,915	4,299
B	0,478	0,423	0,100	1,132	4,774	4,217
C	0,483	0,423	0,095	1,141	5,063	4,437
D	0,478	0,422	0,101	1,132	4,745	4,190
E	0,476	0,421	0,104	1,129	4,569	4,048
F	0,480	0,423	0,098	1,133	4,887	4,313
G	0,481	0,423	0,098	1,137	4,911	4,319
H	0,483	0,423	0,094	1,141	5,113	4,482
I	0,476	0,420	0,105	1,133	4,536	4,004
J	0,478	0,422	0,101	1,131	4,747	4,196
K	0,477	0,420	0,103	1,135	4,614	4,066
L	0,477	0,422	0,102	1,132	4,673	4,128
M	0,477	0,420	0,104	1,135	4,577	4,034
N	0,475	0,420	0,106	1,129	4,479	3,967
O	0,476	0,420	0,105	1,133	4,536	4,002
P	0,474	0,421	0,106	1,127	4,477	3,974
Q	0,474	0,420	0,107	1,130	4,420	3,912
R	0,473	0,420	0,107	1,127	4,406	3,909
S	0,475	0,420	0,106	1,132	4,489	3,967
T	0,474	0,420	0,107	1,129	4,443	3,934
U	0,475	0,420	0,106	1,130	4,482	3,966
V	0,474	0,421	0,106	1,125	4,464	3,968
W	0,477	0,421	0,103	1,134	4,628	4,082
X	0,477	0,421	0,103	1,132	4,623	4,083
Y	0,473	0,421	0,107	1,125	4,418	3,926
Z	0,474	0,421	0,106	1,127	4,458	3,954
AA	0,475	0,421	0,105	1,128	4,509	3,995
AB	0,475	0,421	0,105	1,128	4,514	4,004
AC	0,476	0,420	0,105	1,132	4,535	4,008
AD	0,473	0,421	0,107	1,125	4,425	3,932
AE	0,481	0,421	0,099	1,141	4,860	4,261
AF	0,475	0,422	0,104	1,124	4,564	4,061
AG	0,475	0,421	0,105	1,127	4,505	3,996
AH	0,477	0,421	0,103	1,134	4,632	4,086
AI	0,476	0,422	0,103	1,130	4,614	4,084
AJ	0,476	0,421	0,104	1,129	4,577	4,055
AK	0,475	0,421	0,105	1,127	4,499	3,992
AL	0,477	0,422	0,102	1,131	4,655	4,117
AM	0,475	0,421	0,105	1,129	4,525	4,009
AN	0,473	0,421	0,108	1,123	4,384	3,903
AO	0,476	0,420	0,105	1,131	4,528	4,003
AP	0,474	0,421	0,106	1,125	4,464	3,968
AQ	0,475	0,421	0,105	1,128	4,510	3,997
AR	0,475	0,421	0,105	1,130	4,533	4,010
AS	0,477	0,422	0,103	1,131	4,651	4,114
AT	0,474	0,421	0,106	1,126	4,479	3,979
AU	0,477	0,421	0,104	1,133	4,595	4,055
AV	0,475	0,421	0,105	1,128	4,546	4,029
AW	0,473	0,421	0,107	1,124	4,408	3,922
AX	0,474	0,421	0,106	1,128	4,477	3,969
AY	0,472	0,419	0,109	1,127	4,328	3,841
AZ	0,477	0,420	0,104	1,136	4,609	4,056

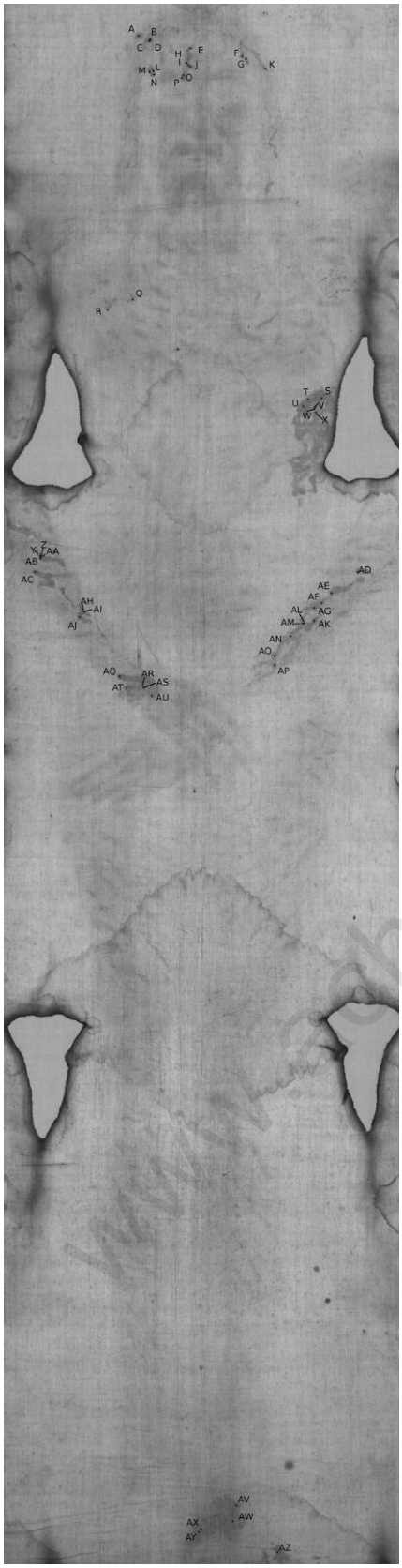

Figure 9. Bloodstains colorimetric data acquisition point in front side.

TABLE 4. Colorimetric data acquired in reference to fig.8.

Ref.	x	y	z	x/y	x/z	y/z
A	0,489	0,416	0,095	1,175	5,146	4,379
B	0,490	0,417	0,094	1,175	5,202	4,426
C	0,495	0,417	0,089	1,187	5,546	4,671
D	0,495	0,416	0,090	1,189	5,491	4,620
E	0,488	0,418	0,096	1,168	5,083	4,353
F	0,489	0,417	0,095	1,172	5,173	4,412
G	0,492	0,416	0,094	1,183	5,239	4,429
H	0,493	0,418	0,091	1,180	5,438	4,610
I	0,491	0,414	0,097	1,186	5,074	4,279
J	0,492	0,418	0,091	1,177	5,386	4,577
K	0,489	0,419	0,093	1,167	5,262	4,508
L	0,491	0,418	0,092	1,176	5,310	4,516
M	0,489	0,417	0,094	1,172	5,205	4,440
N	0,491	0,418	0,093	1,175	5,288	4,500
O	0,492	0,418	0,091	1,177	5,430	4,613
P	0,493	0,419	0,089	1,178	5,509	4,677
Q	0,491	0,421	0,088	1,166	5,564	4,773
R	0,485	0,420	0,095	1,155	5,088	4,406
S	0,488	0,416	0,097	1,171	5,021	4,287
T	0,487	0,415	0,099	1,174	4,918	4,188
U	0,487	0,415	0,098	1,173	4,965	4,232
V	0,489	0,417	0,095	1,171	5,147	4,396
W	0,489	0,417	0,095	1,173	5,174	4,411
X	0,488	0,416	0,096	1,172	5,067	4,322
Y	0,489	0,417	0,095	1,174	5,138	4,377
Z	0,488	0,417	0,096	1,172	5,077	4,334
AA	0,488	0,416	0,097	1,172	5,011	4,276
AB	0,484	0,416	0,101	1,162	4,794	4,126
AC	0,484	0,417	0,100	1,163	4,849	4,171
AD	0,492	0,420	0,089	1,172	5,526	4,714
AE	0,487	0,418	0,097	1,165	5,040	4,326
AF	0,484	0,418	0,099	1,158	4,910	4,238
AG	0,488	0,416	0,097	1,171	5,021	4,287
AH	0,487	0,414	0,100	1,179	4,880	4,141
AI	0,486	0,415	0,100	1,172	4,855	4,143
AJ	0,485	0,416	0,100	1,165	4,874	4,185
AK	0,492	0,418	0,090	1,176	5,444	4,628
AL	0,486	0,417	0,098	1,164	4,966	4,268
AM	0,485	0,417	0,099	1,161	4,893	4,214
AN	0,487	0,418	0,096	1,166	5,081	4,357
AO	0,484	0,417	0,100	1,160	4,850	4,183
AP	0,488	0,419	0,094	1,163	5,189	4,462
AQ	0,490	0,415	0,097	1,181	5,070	4,294
AR	0,488	0,417	0,096	1,169	5,067	4,336
AS	0,486	0,418	0,097	1,163	4,989	4,289
AT	0,490	0,416	0,096	1,178	5,117	4,343
AU	0,484	0,417	0,101	1,161	4,805	4,139
AV	0,486	0,416	0,098	1,168	4,955	4,243
AW	0,485	0,416	0,100	1,166	4,824	4,137
AX	0,484	0,416	0,101	1,164	4,818	4,140
AY	0,484	0,415	0,102	1,167	4,772	4,088
AZ	0,486	0,416	0,099	1,167	4,907	4,204

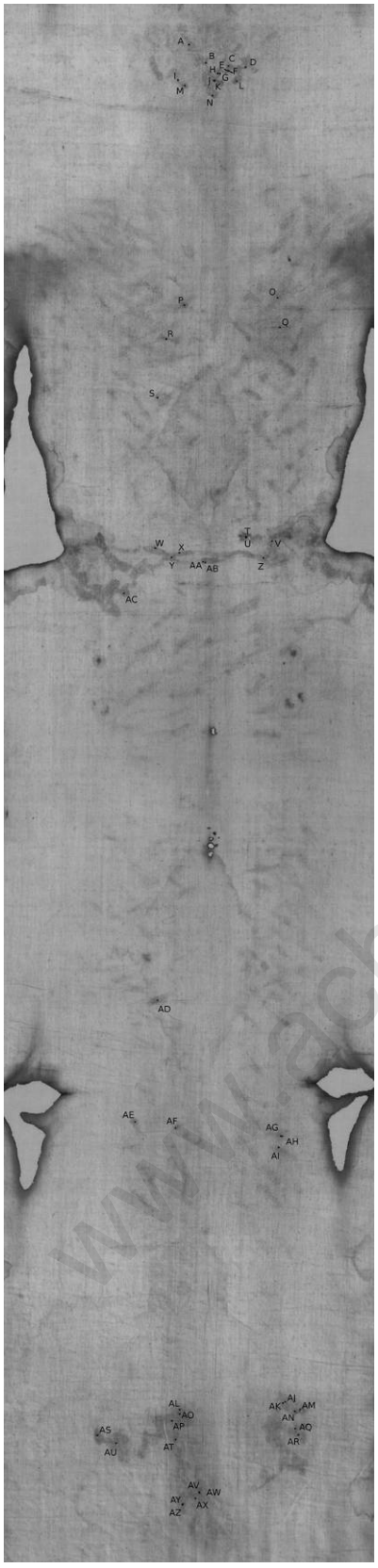

Figure 10. Bloodstains colorimetric data acquisition point in the back side.

TABLE 5. Colorimetric data acquired in reference to fig.9.

Ref.	x	y	z	x/y	x/z	y/z
A	0,490	0,420	0,091	1,168	5,373	4,600
B	0,495	0,418	0,088	1,186	5,600	4,724
C	0,491	0,417	0,093	1,176	5,279	4,487
D	0,490	0,417	0,094	1,177	5,209	4,426
E	0,490	0,416	0,096	1,178	5,106	4,335
F	0,489	0,416	0,096	1,177	5,086	4,321
G	0,495	0,417	0,089	1,187	5,548	4,675
H	0,491	0,417	0,093	1,178	5,253	4,458
I	0,491	0,419	0,090	1,172	5,436	4,637
J	0,487	0,414	0,100	1,176	4,875	4,144
K	0,488	0,415	0,098	1,174	4,970	4,231
L	0,492	0,416	0,093	1,183	5,311	4,491
M	0,489	0,415	0,097	1,180	5,019	4,254
N	0,489	0,417	0,095	1,174	5,160	4,395
O	0,489	0,419	0,093	1,168	5,240	4,487
P	0,495	0,418	0,088	1,185	5,599	4,726
Q	0,493	0,418	0,090	1,177	5,471	4,648
R	0,493	0,420	0,088	1,173	5,605	4,779
S	0,493	0,422	0,086	1,167	5,698	4,881
T	0,495	0,415	0,092	1,193	5,380	4,509
U	0,494	0,415	0,091	1,190	5,412	4,547
V	0,493	0,419	0,089	1,177	5,529	4,697
W	0,490	0,420	0,091	1,166	5,387	4,621
X	0,490	0,420	0,090	1,166	5,440	4,664
Y	0,485	0,417	0,099	1,162	4,892	4,212
Z	0,490	0,417	0,093	1,174	5,251	4,471
AA	0,489	0,418	0,094	1,171	5,180	4,424
AB	0,493	0,419	0,089	1,177	5,529	4,697
AC	0,489	0,419	0,093	1,167	5,275	4,518
AD	0,493	0,420	0,088	1,172	5,576	4,757
AE	0,487	0,421	0,094	1,158	5,194	4,487
AF	0,485	0,420	0,096	1,154	5,034	4,364
AG	0,485	0,419	0,097	1,158	4,997	4,316
AH	0,488	0,421	0,093	1,159	5,247	4,526
AI	0,491	0,421	0,089	1,164	5,534	4,753
AJ	0,487	0,417	0,097	1,166	5,013	4,300
AK	0,485	0,418	0,098	1,159	4,968	4,286
AL	0,488	0,417	0,096	1,171	5,083	4,340
AM	0,488	0,417	0,096	1,170	5,101	4,359
AN	0,487	0,416	0,097	1,170	5,000	4,273
AO	0,491	0,417	0,094	1,178	5,232	4,442
AP	0,486	0,416	0,100	1,168	4,875	4,173
AQ	0,486	0,417	0,098	1,166	4,973	4,265
AR	0,484	0,417	0,099	1,161	4,875	4,198
AS	0,494	0,417	0,091	1,184	5,442	4,596
AT	0,486	0,417	0,099	1,166	4,913	4,215
AU	0,489	0,417	0,094	1,173	5,188	4,424
AV	0,491	0,414	0,096	1,185	5,096	4,302
AW	0,491	0,416	0,094	1,182	5,209	4,408
AX	0,485	0,417	0,099	1,165	4,921	4,225
AY	0,488	0,417	0,096	1,172	5,071	4,327
AZ	0,486	0,416	0,098	1,168	4,942	4,232

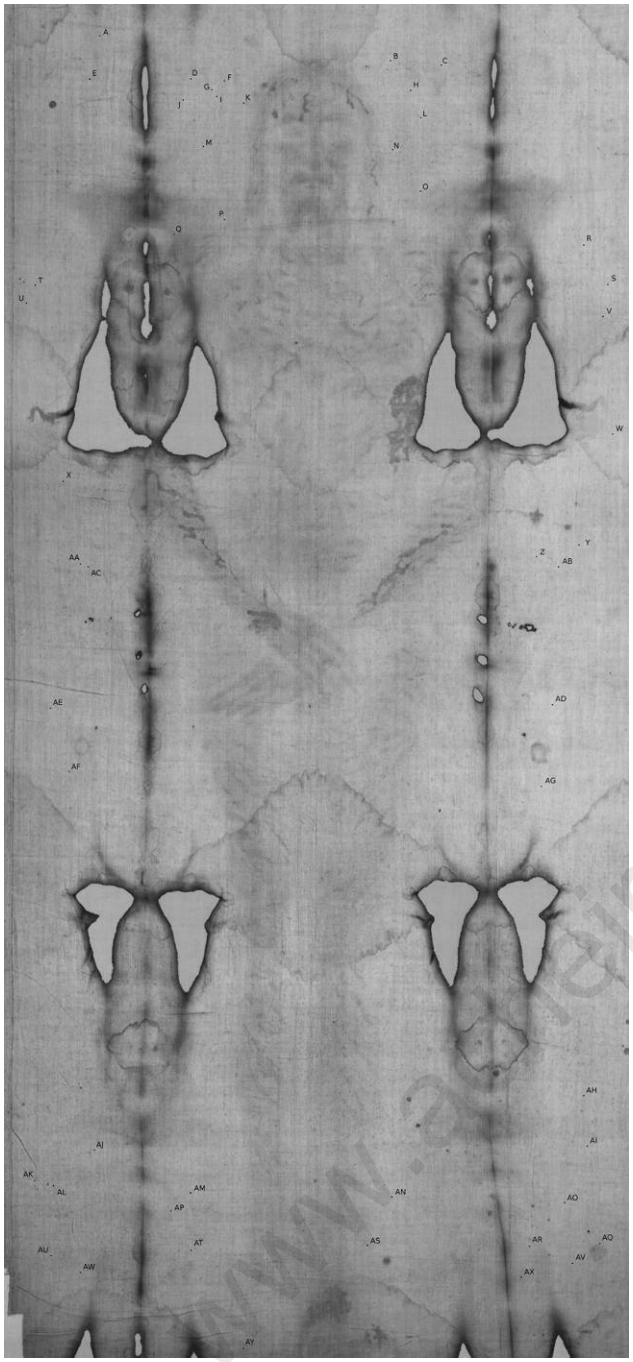

Figure 11. Cloth colorimetric data acquisition point in front side.

TABLE 6. Colorimetric data acquired in reference to fig.10.

Ref.	x	y	z	x/y	x/z	y/z
A	0,471	0,418	0,112	1,127	4,209	3,736
B	0,469	0,419	0,112	1,119	4,171	3,728
C	0,471	0,420	0,110	1,121	4,297	3,833
D	0,469	0,418	0,114	1,121	4,107	3,664
E	0,471	0,418	0,112	1,127	4,218	3,743
F	0,473	0,420	0,108	1,125	4,368	3,882
G	0,469	0,418	0,114	1,121	4,127	3,683
H	0,470	0,420	0,111	1,119	4,220	3,770
I	0,470	0,419	0,113	1,122	4,164	3,712
J	0,470	0,419	0,113	1,123	4,177	3,720
K	0,472	0,420	0,109	1,125	4,310	3,833
L	0,471	0,420	0,110	1,120	4,271	3,815
M	0,471	0,419	0,110	1,123	4,266	3,798
N	0,470	0,420	0,111	1,120	4,232	3,780
O	0,473	0,420	0,107	1,126	4,403	3,912
P	0,475	0,420	0,107	1,131	4,453	3,936
Q	0,473	0,420	0,107	1,126	4,403	3,912
R	0,474	0,420	0,107	1,128	4,436	3,932
S	0,471	0,420	0,110	1,121	4,267	3,806
T	0,469	0,419	0,113	1,120	4,136	3,692
U	0,471	0,419	0,111	1,124	4,261	3,792
V	0,474	0,420	0,106	1,128	4,463	3,956
W	0,469	0,419	0,112	1,119	4,177	3,733
X	0,472	0,419	0,110	1,125	4,283	3,806
Y	0,473	0,421	0,108	1,124	4,398	3,914
Z	0,470	0,419	0,111	1,121	4,234	3,776
AA	0,471	0,419	0,111	1,123	4,232	3,769
AB	0,469	0,420	0,111	1,117	4,211	3,769
AC	0,469	0,418	0,114	1,121	4,097	3,654
AD	0,470	0,419	0,112	1,121	4,215	3,761
AE	0,474	0,420	0,107	1,128	4,431	3,930
AF	0,475	0,420	0,106	1,129	4,465	3,953
AG	0,472	0,421	0,108	1,120	4,371	3,901
AH	0,475	0,422	0,104	1,127	4,552	4,038
AI	0,475	0,422	0,104	1,127	4,552	4,038
AJ	0,470	0,420	0,111	1,119	4,248	3,797
AK	0,474	0,419	0,108	1,129	4,393	3,890
AL	0,474	0,420	0,107	1,128	4,420	3,919
AM	0,473	0,420	0,109	1,127	4,348	3,859
AN	0,470	0,420	0,111	1,120	4,245	3,790
AO	0,473	0,421	0,107	1,123	4,423	3,938
AP	0,475	0,421	0,105	1,130	4,534	4,011
AQ	0,476	0,421	0,104	1,130	4,555	4,033
AR	0,475	0,421	0,105	1,128	4,523	4,011
AS	0,472	0,419	0,110	1,124	4,284	3,811
AT	0,475	0,420	0,106	1,130	4,467	3,953
AU	0,475	0,420	0,106	1,129	4,494	3,979
AV	0,472	0,420	0,109	1,123	4,324	3,850
AW	0,481	0,421	0,099	1,140	4,857	4,259
AX	0,479	0,422	0,101	1,135	4,758	4,194
AY	0,484	0,421	0,096	1,148	5,017	4,369
AZ	0,471	0,420	0,111	1,121	4,255	3,796

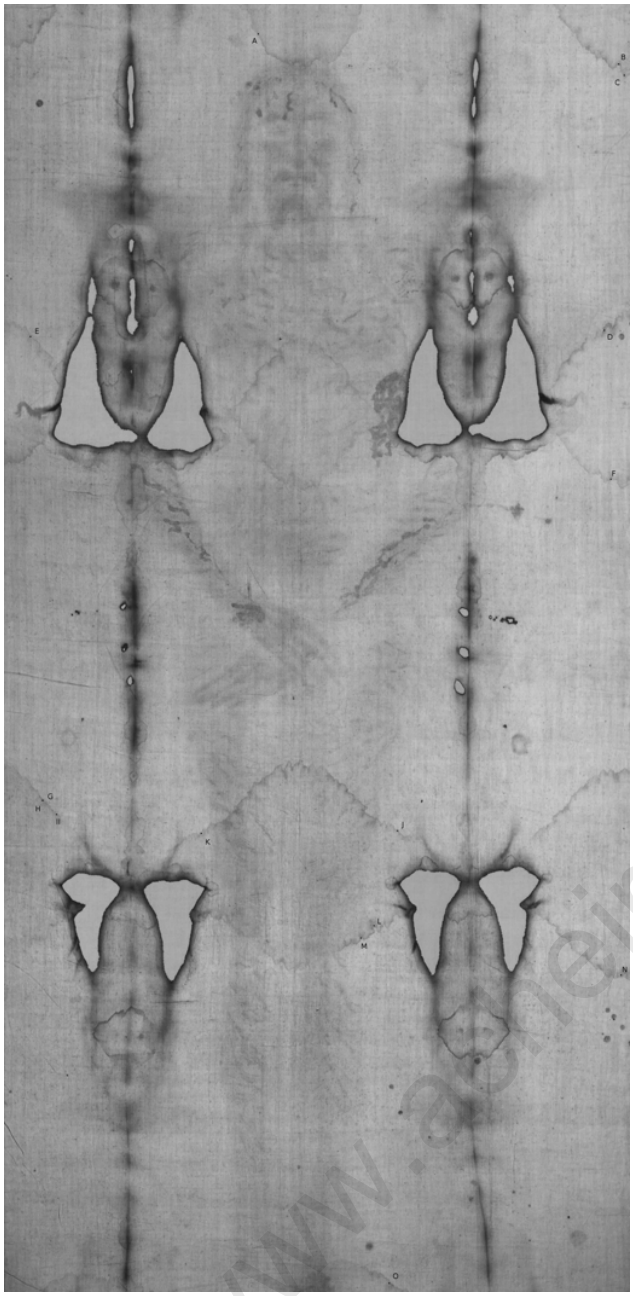

Figure 12. Water stains colorimetric data acquisition point in front side.

TABLE 7. Colorimetric data acquired in reference to fig.11.

Ref.	x	y	z	x/y	x/z	y/z
A	0,481	0,422	0,098	1,140	4,893	4,291
B	0,492	0,424	0,085	1,160	5,796	4,996
C	0,483	0,423	0,095	1,141	5,096	4,468
D	0,493	0,424	0,084	1,162	5,889	5,068
E	0,478	0,420	0,103	1,138	4,619	4,060
F	0,482	0,422	0,097	1,142	4,985	4,366
G	0,485	0,422	0,094	1,151	5,143	4,470
H	0,485	0,422	0,095	1,150	5,125	4,456
I	0,478	0,421	0,102	1,136	4,669	4,111
J	0,482	0,423	0,096	1,139	5,004	4,394
K	0,480	0,422	0,099	1,138	4,846	4,259
L	0,482	0,423	0,095	1,139	5,062	4,446
M	0,485	0,423	0,093	1,146	5,217	4,551
N	0,480	0,422	0,099	1,136	4,843	4,263
O	0,487	0,418	0,095	1,165	5,113	4,388
P	0,488	0,422	0,091	1,157	5,357	4,631