The importance of the analysis of imperial portraits on Roman coins, for dating the withdrawal from Dacia province

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Abstract *– This study proposes, based on image processing of the imperial portraits of Aurelianus and Claudius II Gothicus presented on coins, the dating of the coins issued by Aurelianus with the legend DACIA FELIX. Based on this dating and taking into account arguments and historical considerations, the date of the withdrawal of the Roman administration from the Dacia would be assessed.*

Keywords – *coins issued by Aurelianus and Claudius II, image processing of imperial portrait on coins, correlation coefficients, structural similarity index (SSIM), dating the withdrawal of the Roman administration from the Dacia Province*

1. INTRODUCTION

The image processing involving ancient coins is a topic that has been addressed in other scientific papers as well [1], [2], [3], [4]. However, none of these concerned the use of image processing as a later invoked argument for dating historical events.

During history's different époques, particularly when referring to the antiquity – period for which the documents are not so frequent comparing to Middle Ages and modern times, there are some historical events that can be explained indirectly, by analyzing the scarce existing vestiges with technical support.

Such a case is represented by the problem concerning the dating of the Roman withdrawal from the *Dacia* Province that so far we know that it took place during the reign of the emperor *Aurelianus*. In recent times, some historians tried to find a precise date for this event, the opinions being divided on two distinct direction: some of them (Th. Bernard, H. Schiller, V Parvan, J. Jung, C. Brandis, M. Macrea, C. Daicoviciu) are placing the retreat in the early years of *Aurelianus*'s reign and others (Br. Rappaport, E. Ritterling, A. D. Xenopol, R. Vulpe, N. Gudea) – at its end. [5]

Thus, based on analyzing the numismatic argument, the presented paper places the retreat of the Roman administration and army at the beginning of *Aurelianus*'s reign.

2. HISTORICAL CONSIDERATIONS

Until the Roman withdraw, *Dacia* appears on the coins of *Claudius II* and *Aurelianus*, the province's feminine allegory being backed by the legend DACIA FELIX. Virtually, both emperors resume the monetary type used two decades ago by *Traianus Decius*. [5], [6]

If the coins issued by Claudius II are certainly referring to the *Dacia* founded by *Traianus*, certain doubts could raise the coins stricken by *Aurelianus*: should they be attributed to the North Danube *Dacia* or the Southern one, created by Aurelian?

Taking into account the rudimentary style of *Aurelianus*' coins bearing the reverse DACIA FELIX, it can be concluded that they were issued before the Emperor's monetary reform (that took place between 273-275 p.Ch), sometime during the first two years of his reign. This dating is also reinforced by the absence from the exergue of the letters XXI or KA, which were typical for the post-reform *antoniniani*. [5], [6]

Thus, the coins bearing the reverse DACIA FELIX refer to the "*Traianus*'s *Dacia*" and consequently the withdrawal could have taken place in 271 AD, but certainly not after 272 AD. In addition, the hypothesis of the representation of the North Danube *Dacia* is also certified by the lack of monetary issues with *Dacia* (even the southern one) after 272 and until the territorial-administrative reform of *Diocletianus*. [6], [6]

During the reign of *Claudius II*, *Dacia* is the only province numismatically represented, these coins being most likely stricken at *Mediolanum* after the *Naissus* victory against the Goths, when the direct connection with the North-Danubian territories was resumed and consequently, *Dacia* being again (for Roman propaganda) a FELIX province. [5], [6]

In the case of *Aurelianus*, *Dacia* is also the only province represented as such, these coins being emitted also in the mint of *Mediolanum* (mint that was replaced after *Aurelianus*'s monetary reform by *Ticinum*). [5], [6]

3. METHODS AND RESULTS

Given the fact that it is not known exactly when the withdraw took place, and even if *Aurelianus*'s coins with DACIA FELIX reverse were pre-reformed stricken, they

could represent either the North-Danube or the South Danube *Dacia*. A clear identification could be made only if these coins would be dated precisely at the beginning of Aurelian's reign.

Thus, if these coins were emitted in 270 AD, *Aurelianus*'s portrait should resemble that of *Claudius II* and be different from that of the years after the reform (273-275 AD). So, *Aurelianus* should be "a kind of *Claudius II*", slightly adjusted (such adjustments to the previous emperor portrait still existed in the Roman imperial mint).

Consequently, dating the *Aurelianus*'s DACIA FELIX coins can only be done through an interdisciplinary approach: biometry and image processing (a previous approach on this topic is discussed in [7]).

Some complex methods used for assessing the image quality generally involve a preprocessing stage (consisting in image alignment, point-wise nonlinear transform, low-pass filtering and color space transformation), followed by a channel decomposition that implies the transformation of the image in different spatial frequencies and assigning selective sub-bands. The final stage of these methods consists in the normalization of the error (it deals with the errors within the signal, caused by intra or inter-channel transform coefficients) and the error pooling, that aims to combine errors from different sub-bands into a single distortion value. [8], [9]

When it comes to computing the similarity between two images, a number of algorithms can be used: the Pearson Correlation Coefficient, the Tanimoto Measure, the Stochastic Sign Change, the Deterministic Sign Change, the Minimum Ratio method, the Spearman's Rho, the Kendall's Tau, the Greatest Deviation method, the Ordinal Measure, the Correlation Ratio, the Energy of Joint Probability Distribution, the Material Similarity, the Shannon Mutual Information method, the Rényi Mutual Information (Rényi entropy), the Tsallis Mutual Information or the F-Information Measures method. [10]

The calculation of the structural similarity index represents another way of comparing images, being a method that can provide superior results comparing to other image quality metrics. [8]

According to previous studies, the calculation of the structural similarity index, when comparing two images X and Y), can be performed in the way described by figure 1 [9]:

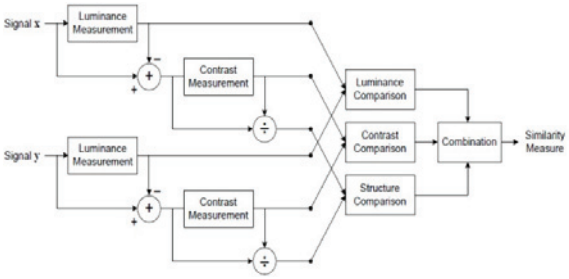

Fig. 1. Block diagram used for assesing the similarity between two images X and Y (proposed in [9])

In order to fulfill this approach, three different coins were selected. One considered the template, stricken by *Aurelianus* (bearing the reverse DACIA FELIX) and two other coins: one issued by *Claudius II Gothicus* in the final part of his reign (AEQVITAS AVG reverse) and another stricken by *Aurelianus* in the last part of his reign, after the monetary reform (ORIENS AVG reverse).

Fig. 2. The coins that have been subjected to biometric investigation:
a) *Aurelianus* (DACIA FELIX reverse)
b) *Claudius II Gothicus* (AEQVITAS reverse)
c) *Aurelianus* (ORIENS AVG reverse)

For these three coins, an image processing of the portraits of the emperors was performed.

The two images that have to be compared to the template were subjected to two transformations (scaling and rotations), in order to achieve the alignment with the template.

Then, in order to perform the geometrical transformation, two reference points were chosen on each coin for the first measurements and then, for the second, three points chosen.

Thus, the resulted images had the same orientation as the template; furthermore, the distances between the points chosen on the template and those on each of the two analyzed coins were identical

After the image alignment process is completed, some similarity scores were computed. There are many proposed and validated approaches for different application domains, related to the design and implementation of the algorithms able to produce such a score as an objective measure of the similarity. Some of them will be presented in what follows.

a) Determining the transformations for alignment, considering two reference points for each coin

The two reference points chosen for the geometrical transformations in order to obtain the coins' alignment are presented in figure 3:

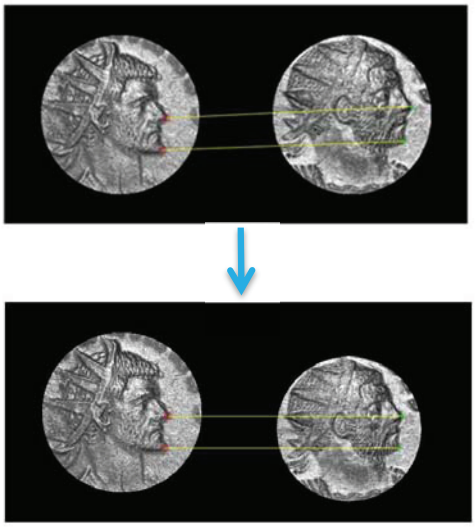

Fig. 3a. Geometrical transformations for the two coins issued by *Aurelianus* (reverses DACIA FELIX and ORIENS AVG)

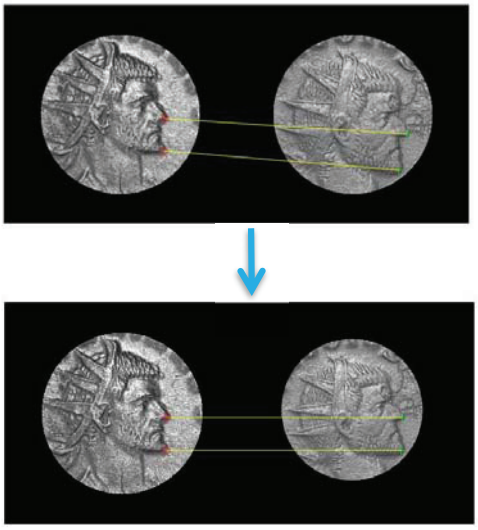

Fig. 3b. Geometrical transformations for the coin issued by *Aurelianus*: (DACIA FELIX reverse) and that issued by *Claudius II Gothicus* (AEQVITAS AVG reverse)

The correlation functions for each of the two pairs of images are presented in figure 4:

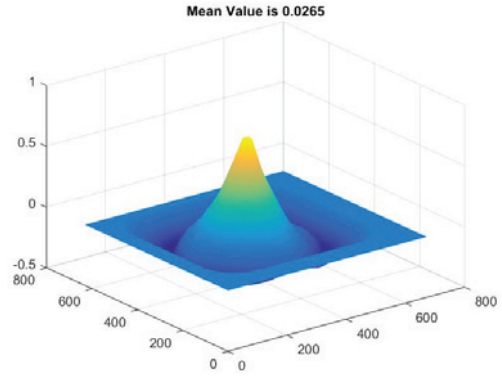

Fig. 4a. 3D graphic presenting the correlation coefficients between the twoo coins issued by *Aurelianus* (reverses DACIA FELIX and ORIENS AVG)

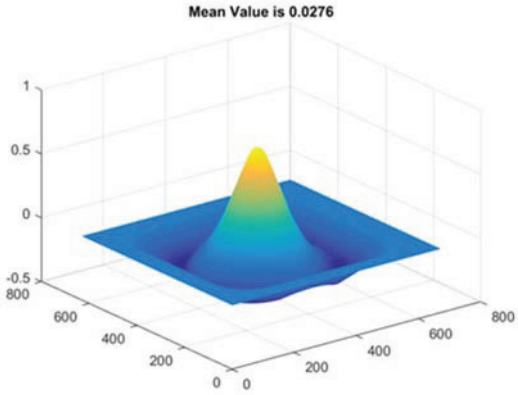

Fig. 4b. 3D graphic presenting the correlation coefficients between the coin issued by *Aurelianus*: (DACIA FELIX reverse) and that issued by *Claudius II Gothicus* (AEQVITAS AVG reverse)

One can observe that the mean value of the correlation coefficients has a bigger value (0,0276) for the situation concerning the coin of *Aurelianus* (DACIA FELIX reverse coin) and that of *Claudius II* (AEQVITAS AVG reverse), comparing with the case concerning the coins issued by *Aurelianus* (reverses DACIA FELIX and ORIENS AVG), when the values is smaller (0,0265).

b) Determining the transformations for alignment, considering three reference points for each coin

The three reference points chosen for the geometrical transformations in order to obtain the coins' alignment are presented in figure 5:

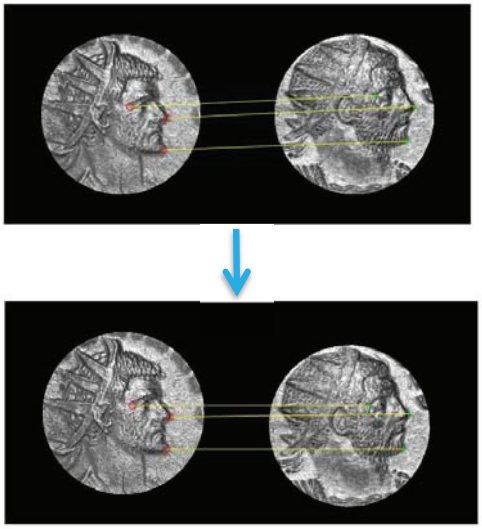

Fig. 5a. Geometrical transformations for the two coins issued by *Aurelianus* (reverses DACIA FELIX and ORIENS AVG)

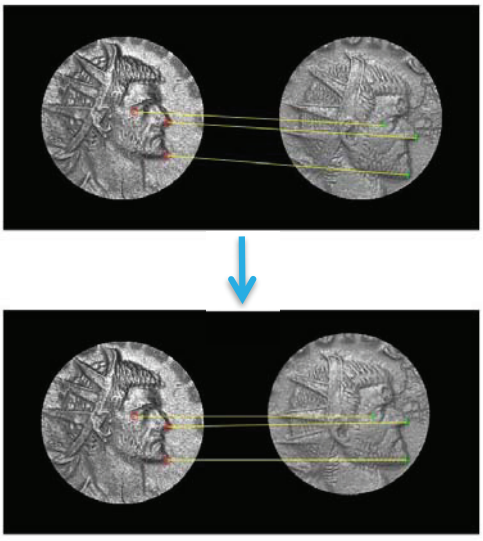

Fig. 5b. Geometrical transformations for the coin issued by *Aurelianus*: (DACIA FELIX reverse) and that issued by *Claudius II Gothicus* (AEQVITAS AVG reverse)

The correlation functions for each of the two pairs of images are presented in figure 6:

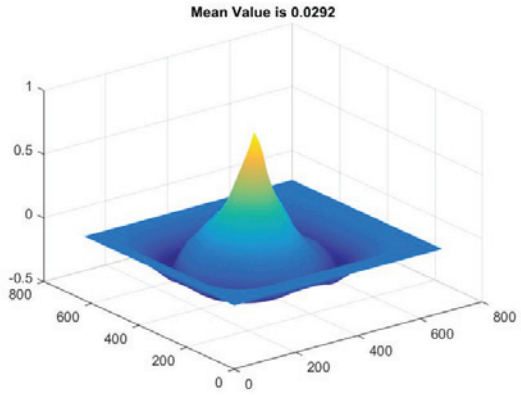

Fig. 6a. 3D graphic presenting the correlation coefficients between the twoo coins issued by *Aurelianus* (reverses DACIA FELIX and ORIENS AVG)

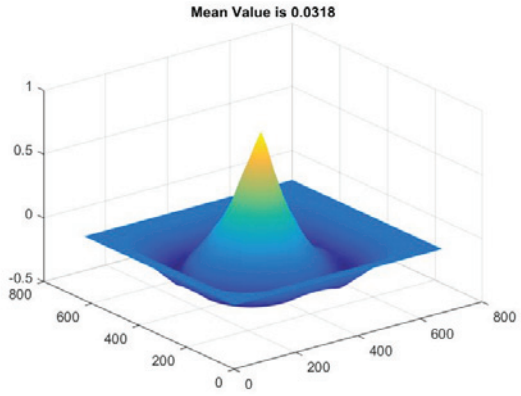

Fig. 6b. 3D graphic presenting the correlation coefficients between the coin issued by *Aurelianus*: (DACIA FELIX reverse) and that issued by *Claudius II Gothicus* (AEQVITAS AVG reverse)

One can observe once more that the mean value of the correlation coefficients has a bigger value (0,0318) for the situation concerning the coin of *Aurelianus* (DACIA FELIX reverse) and that of *Claudius II* (AEQVITAS AVG reverse), comparing to the case concerning the coins issued by *Aurelianus* (reverses DACIA FELIX and ORIENS AVG), case in which the value is smaller - (0,0292).

Furthermore, the computation of the similarity for the two pairs of images (for 2 and 3 points) was performed. The results are presented in figure 7:

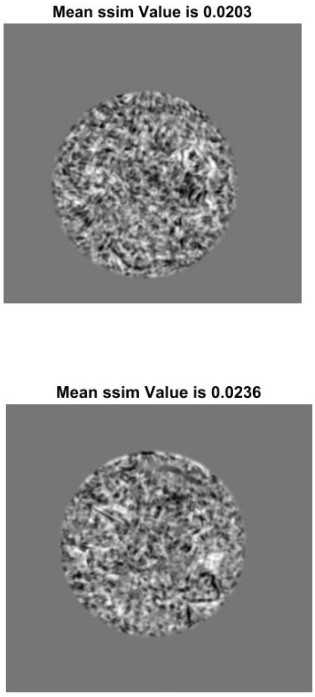

Fig. 7a The calculus of similarity for the two pairs of images, for two points

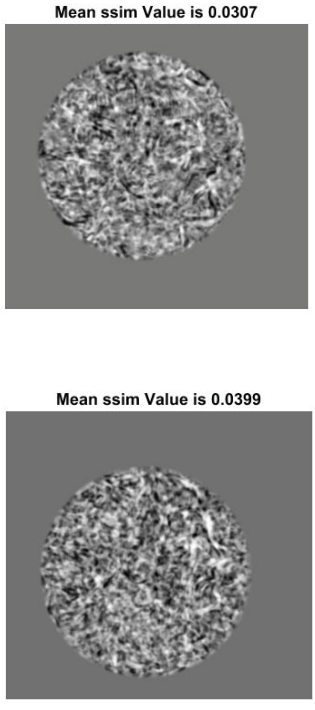

Fig. 7b The calculus of similarity for the two pairs of images, for three points

One can observe that in both cases (two or three points chosen on the images), the mean values are greater in the case of the pair *Aurelianus* DACIA FELIX reverse – *Claudius II Gothicus* AEQVITAS reverse (0,0236 for two points and 0,0399 for three points) than in the case of the pair *Aurelianus* DACIA FELIX reverse - *Aurelianus* ORIENS AVG reverse (0,0203 and 0,0307). That is an indication that the portrait of *Aurealinus* at the beginning of his reign, when the coins with DACIA FELIX reverse were issued, has more similarities with the portrait of *Claudius II Gothicus* in the last part of his reign, than with the portrait of *Aurelianus* after the monetary reform (second part of his reign). Also, when increasing the number of points from 2 to 3, the values of the mean coefficients are increasing.

4. CONCLUSIONS

The presented paper presents the analysis of the imperial portraits on three different coins (*antoniniani*), one issued by *Claudius II Gothicus* and two stricken by *Aurelianus* (one issued at the beginning of his reign with the DACIA FELIX reverse and the other, from in the second half of his reign, after the monetary reform)

Although it was visible prior to our demarche, following the analysis it was demonstrated by using an objective measure that the coin issued by *Aurelianus* with the reverse DACIA FELIX presents on the obverse a portrait of the emperor different from that of the subsequent years of the reign and closer to that of *Claudius II*.

These coins must have been stricken immediately after *Claudius II* 's death (perhaps in 270 AD), when the engravers were still not familiar with the figure of *Aurelianus* and had been forced to use for the monetary die an intermediate portrait, of transition, from the figure of one emperor to that of the other.

Thus, the coins of Aurelian with the reverse DACIA FELIX were stricken in the mint of *Mediolanum*, immediately after *Aurelianus*'s imperial ascension; consequently, they must represent the *Dacia* founded by *Traianus*.

The absence of the coins with Dacia after the monetary reform (273-275 AD) and at the subsequent emperors strengthens our belief that the representation of *Dacia* under *Aurelianus* refers only to the North-Danubian *Dacia*, which was abandoned sometime at the beginning of his reign, but until the monetary reform (most probably in 271 AD).

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