From Reconstruction to Analysis. Re-use and Re-purposing of 3D Scan Datasets Obtained from Ancient Greek Marble Sculpture

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The paper describes two related research projects concerning the sculptural decoration of a well-known classical Greek monument, the temple of Zeus at Olympia. Both projects are based on the same data set, i.e., the 3D scans obtained from the original pieces of marble sculpture, but they are used for two completely different purposes. In the first section, a summary is given of earlier results concerning the virtual 3D reconstruction of the east pediment, the second part describes another research question, the identity of the so-called Olympia master and a new analytical method, which makes use of the possibilities offered by the digital datasets and may open up new perspectives for the traditional art historical analysis. Beside the re-using and re-purposing of the raw data, the 3D models are not the final output of the project, but they are used to enhance our knowledge in a new way, which would be hardly feasible with traditional methods.

Key words:
3D models, ancient Greek sculpture, temple of Zeus, Olympia, art-historical analysis, Morellian method

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1. INTRODUCTION

The surviving fragments of the temple of Zeus at Olympia are substantial and numerous enough to enable a fairly reliable reconstruction of the building and of its sculptural decoration. This has already been done at the end of the 19th century and has justly received general acceptance till today. However, there are some details which are still controversial and concern crucially important aspects of the monument. By creating a new and accurate digital reconstruction of the temple and its sculptures, it was intended to investigate one of these problems, the arrangement of the central figures of the east pediment. The reconstruction project was therefore not simply motivated by the

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need for an aesthetically more pleasing visualization, but the models were used to solve a specific research question. In addition, the data captured for the reconstruction project could be re-used to address another problem, the identification of the so-called Olympia-Master.

2. DIGITAL RECONSTRUCTION OF THE EAST PEDIMENT

The arrangement of the five central figures was continuously debated among archaeologists and art historians since the discovery of the fragments more than a century ago. [Herrmann 1987] The basic problem is that the fragments themselves can be arranged in four substantially different ways and there are no obvious clues for choosing the most probable one. The position of the male figures is indicated by the terms closed or open, the arrangement of the females by Type "A"/"B".

Every conceivable reconstruction (Fig. 1) has already been advocated by certain scholars for various aesthetic, technical, philological, archaeological and other considerations, but the different reconstructions were most often presented only in simple drawings, ignoring the three-dimensional form of the statues [Säflund 1970, 11-59]. In addition, important results achieved and confirmed by a long series of experimentation with miniature or life-size plaster casts [Treu 1897, Studniczka 1924, Bulle 1939] were also ignored in general.

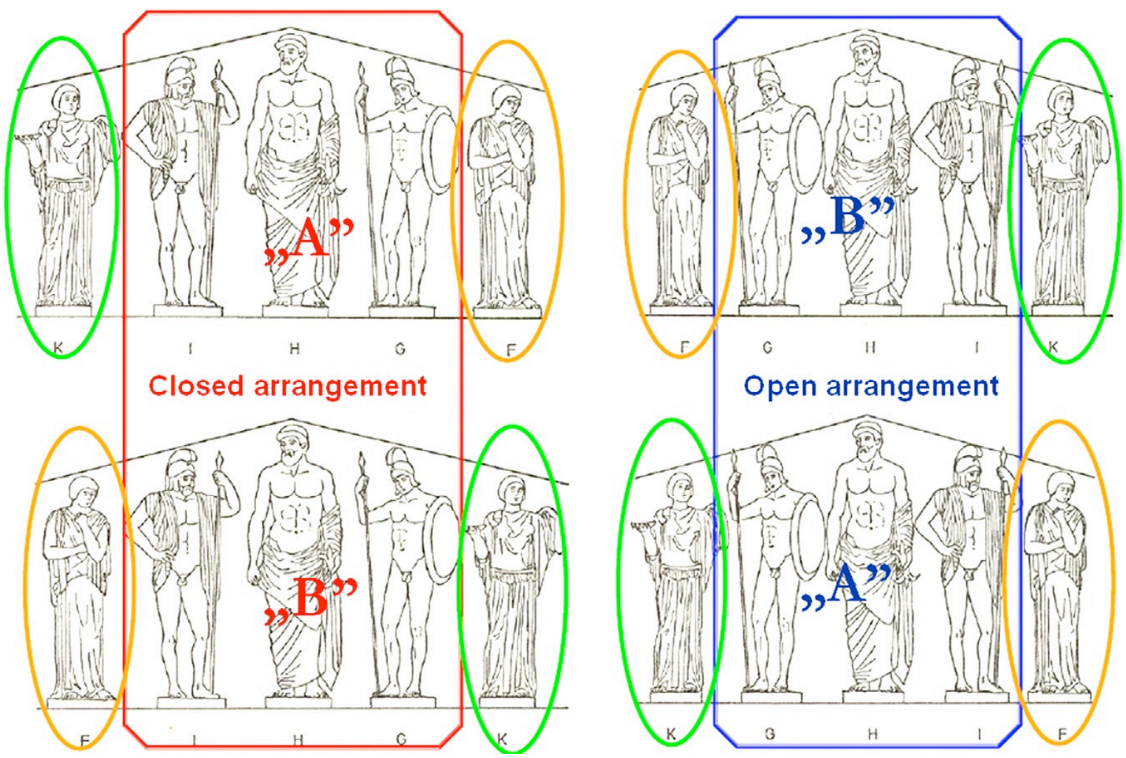

Figure 1. Conceivable reconstructions of the central group of the east pediment

The virtual model of the pedimental group was thus created in order to test all the earlier hypotheses and observations and the experiments carried out with the new digital 3D models were definitely able to clarify the case [Patay-Horváth 2011]. One can thus confidently conclude that the reconstruction which is most widely accepted today (open arrangement Type “A”), is technically the most difficult to realize and would be feasible only if we ignored a general convention of ancient Greek art regarding the length and the way of holding a spear. For the same reason, open arrangement Type “B” can also be ruled out. By considering every piece of available evidence (e.g. find circumstances), one can finally conclude that the most probable reconstruction is the closed arrangement Type “A”, illustrated in Fig. 2 [Patay-Horváth 2013].

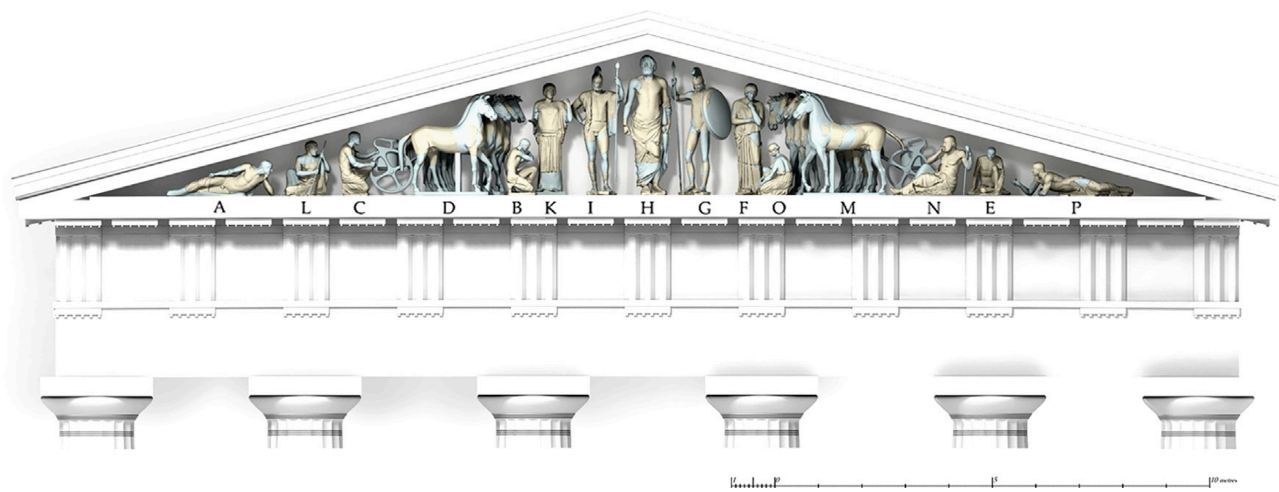

Figure 2. Reconstruction of the east pediment according to the closed arrangement Type A

3. ANALYSIS OF DIGITAL 3D MODELS

3.1 The problem of the “Olympia master”

Perhaps the most difficult and the most distressing problem of the Olympia sculptures regards the identity of the master(s) of these works. Despite the high artistic quality and their excellent workmanship, nobody really knows who the sculptor (or the sculptors) of these pieces actually was (were) and where he (they) came from. In order to answer this question, i.e., to determine the place of origin of the so-called “Olympia master(s)” a project has been recently started which tries to combine the possibilities offered by the latest 3D scanning technologies with a traditional art historical method. This 3D-analysis is expected to enable the identification of individual master sculptors and workshops in general and to reveal something about the origins of the “Olympia-master(s)” in particular. The method developed may easily be applied or adapted to many other similar problems of classical archaeology and the history of art in general.

3.2 History of research

Classical archaeologists realized very early that the only available ancient literary source (Pausanias 5. 10. 7) is most likely to be unreliable and have tried for more than a century to identify the "Olympia master" with a local, an Athenian, a Spartan, a North-Peloponnesian, a Parian or another sculptor, but practically everybody arrived at different solutions [Herrmann 1987; Dörig 1997; Holloway 2000; Kyrieleis 2006]. All the traditional methods have already been tried to solve the problem, but none has yielded cogent results. Even the basic question—whether there was one single master/workshop or several different ones—remains controversial.

This is certainly owing to the subjectivity of the stylistic judgments and to the relative rarity of original sculpture dating from the given period (the so-called Severe Style, ca. 480-450 BC). But on the other hand, archaeologists have almost exclusively relied on photographs when looking for stylistic parallels. This method worked well in establishing master-hands in two-dimensional art (in the case of ancient Greek art: vase-painting), but is not adequate to the demands of three-dimensional art such as sculpture, because three-dimensional objects can be only partially captured by photographs. The images necessarily conceal some parts of the object and even those which are shown are usually distorted. Moreover, photographs taken with different equipment, under different lighting conditions and from different viewpoints, can hardly be used to compare fine stylistic traits. Simple pieces of sculpture, e.g. archaic Greek standing male and female statues could effectively be studied by this method, but as the complexity of sculpture increases, photographs are no more sufficient. The failure to detect master-hands in the case of classical sculpture is therefore not surprising.

Plaster casts have also occasionally been employed in studying ancient sculpture. These have the advantage of representing the real structure of a three-dimensional work of art, but they are quite expensive and therefore no institute or researcher can afford to have available all the relevant pieces in this medium. Though they enable us to compare pieces which are normally stored in different collections, far away from each other, they are not scalable, making comparisons between them for the human eye difficult. Their handling is not easy either, especially if they are of great dimensions, as in the case of the sculptures from the temple of Zeus. Moreover, it is quite difficult to take measurements from them, and therefore it is only natural, that this has normally not been done thus far.

3.3 New approach using digital 3D models

Virtual 3D models can be used again to escape the inherent difficulties of the hitherto used tools (photographs, plaster casts; Frischer 2015). They can be used for this purpose basically because they are not concealing or distorting any part of the sculpture as photographs do, and in spite of the plaster casts, it is easy to scale and to manipulate them. So, they combine the advantages of the two traditional media and eliminate at the same time the disadvantages of both. In addition, it is e.g. easy to take measurements of any given part of the statues or to create profile drawings from them. Fine details of anatomy and drapery or delicate forms can also be extracted and compared to each other, to detect individual master hands, as it is usually and successfully practised in the case of two-dimensional art.

The method of detecting master-hands in different works of art by observing idiosyncrasies in the rendering of small details has been developed by Giovanni Morelli during the nineteenth century and is commonly referred to as master-hand attribution [Vakkari 2001]. Morelli used it first to distinguish the works of famous Renaissance painters, but the method itself was successfully applied to many other periods. Sir J. D. Beazley first used this method to identify Attic black-figure and red-figure vase-painters, afterwards he applied this method to Etruscan vase-painting, too [Beazley 1947, 1956, 1963, 1971]. His attributions are nowadays generally accepted, and they revolutionized our understanding of ancient art. Many other scholars followed this path and although the names of the Greek vase-painters are irrecoverably lost, one can reconstruct the history and development of Corinthian, Etrusco-Corinthian, Laconian and South-Italian vase-painting by identifying hundreds or thousands of individual oeuvres [Stibbe 1972; Amyx 1988; Trendall 1967, 1982; Szilágyi 1998].

The Morellian method was not unanimously accepted in the nineteenth century, and its application to ancient art provoked some controversy even recently [Whitley 1997; Oakley 1998]. It is true that distinctions between closely related workshops or individual masters are not always clear-cut, and some attributions are reconsidered from time to time, but actually no one questions the basic principle, and no better method has been proposed to tackle the problem. The method seems, according to our present knowledge, to be useful und trustworthy in general and has proved to be applicable in every case where a sufficiently large number of detailed figural representations is available for analysis.

Since the human eye cannot automatically and reliably extract characteristic features from 3D objects, and because photographs cannot faithfully reproduce three-dimensional details, the use of the Morellian attribution method in the analysis of three-dimensional art has been rather limited so far. On the other hand, there have already been some attempts to apply the Morelli-method to three-dimensional art, where the necessary prerequisites (sufficiently large number of detailed, well-preserved figural representations) are assured [Frel 1969]. Personal impressions and subjectivity (naturally inherent in connoisseurship) played a much greater role in these cases than in the analysis of two-dimensional art, and owing to the limitations of traditional photographic documentation, it was impossible to demonstrate the attributions as convincingly as in the case of vase-painting. The obvious biological and technological constraints may, however, be overcome by using virtual 3D models produced by 3D scanning.

Simple comparisons of digital 3D models with each other represents a possibility to detect master-hands in ancient sculpture, and in some special cases even this simple method may yield significant results [Sengoku et. al. 2015], but the more or less exact matching of two or more pieces of sculpture is more likely to be the exception rather than the rule. In addition, in the case of classical Greek marble sculpture, several problems arise from the fragmentary state of preservation and the uniqueness of each piece, which makes comparisons between individual figures or features very difficult.

It seems to be, however, feasible and useful to compare smaller parts of the models, e.g., distinctive anatomical features. Eyes, eyes with accompanying brows, mouths, and noses were extracted from our Olympia models, resulting in a data set of 44 total features. Examples of extracted facial features may be seen in Fig. 3.

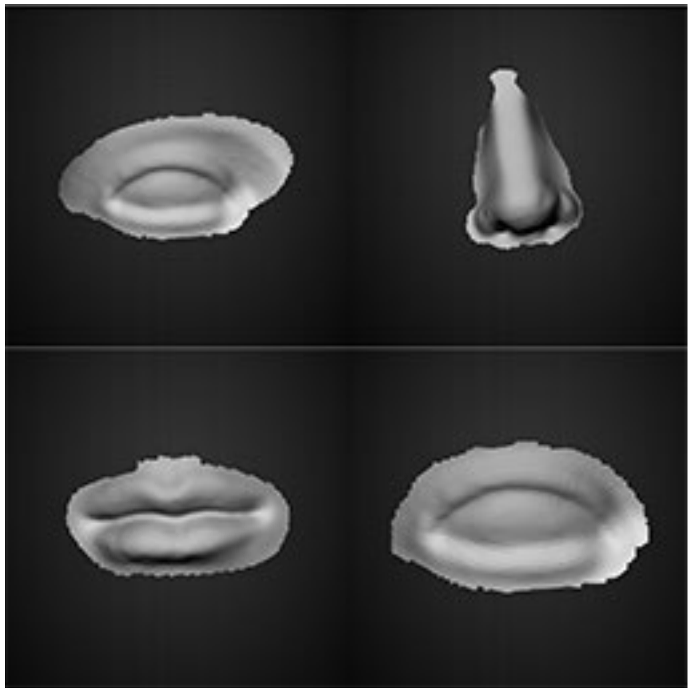

Figure 3. Examples of facial features extracted from the models.

These models were then compared using the open source software Cloud Compare. Cloud Compare was used to compute the mean and standard deviation of the distances between points in two facial feature models. Using Cloud Compare, facial features were aligned so as to maximize the overlap between the two models. Then, for each point in the reference model the closest point was found in the comparison model. Finally, the mean and standard deviation of the distances were calculated. These two values were combined into a single metric using the following equation:

$$d(x) = \max(|mean \pm standard\ deviation|)$$

Each feature was compared to every other, resulting in 43 values per feature.
Then, a two-sample t-test was performed to test whether on average a feature from the West pediment was more similar to other features from the West pediment and whether features from the East pediment were more similar to other features from the East pediment. Only the eyes and eyes with accompanying brows had enough features to perform such a test. A p-value of less than 0.05 is considered significant. Only the right eyes from statues N and O on the east pediment were found to be statistically significant (Fig. 4). Assuming that $d(x)$ may reliably distinguish artists/workshops, we could then conclude that the eyes were all carved by the same artist/workshop.

	files	perc_w	perc_e	f.p.value	t.p.value
1	E_N_eyeL.OBJ	0.6	0.4	0.0917	0.6102
2	E_N_eyeR.OBJ	0.2	0.8	0.9937	0.0196
3	E_O_eyeL.OBJ	0.6	0.4	0.5640	0.0728
4	E_O_eyeR.OBJ	0.4	0.6	0.3127	0.0302
5	E_P_eyeL.OBJ	0.6	0.4	0.3312	0.1168
6	E_P_eyeR.OBJ	0.4	0.6	0.4196	0.0385
7	W_A_eyeL.OBJ	0.8	0.2	0.2200	0.1016
8	W_A_eyeR.OBJ	0.8	0.2	0.3149	0.1634
9	W_B_eyeL.OBJ	0.8	0.2	0.1838	0.3205
10	W_B_eyeR.OBJ	0.8	0.2	0.0712	0.5014
11	W_D_eyeL.OBJ	0.8	0.2	0.0730	0.6274
12	W_D_eyeR.OBJ	0.6	0.4	0.0127	0.2382
13	W_E_eyeL.OBJ	0.4	0.6	0.0081	0.4567
14	W_E_eyeR.OBJ	0.6	0.4	0.6777	0.9316
15	W_I_eyeL.OBJ	0.6	0.4	0.0012	0.1373
16	W_I_eyeR.OBJ	0.8	0.2	0.0155	0.6554
17	W_U_eyeL.OBJ	0.8	0.2	0.0633	0.6175
18	W_U_eyeR.OBJ	0.6	0.4	0.0206	0.2428

Figure 4. Results of statistical tests using values generated from comparing eyes.

In order to perform a visual analysis, the 43 dimensional data points were projected into 3-dimensional space using PCA. When graphed, one may see distinct clusters for each facial feature except for mouths. This is likely due to the fact that the mouths once extracted were for the most part smooth surfaces with few distinguishing features, essentially being flat planes. Regardless, Fig. 5 shows that this method is able to reliably distinguish between the different facial features.

The ability of this technique to detect subtle features characteristic of artists'/workshops' hands may be tested more definitively using pieces for which the artists are already known.

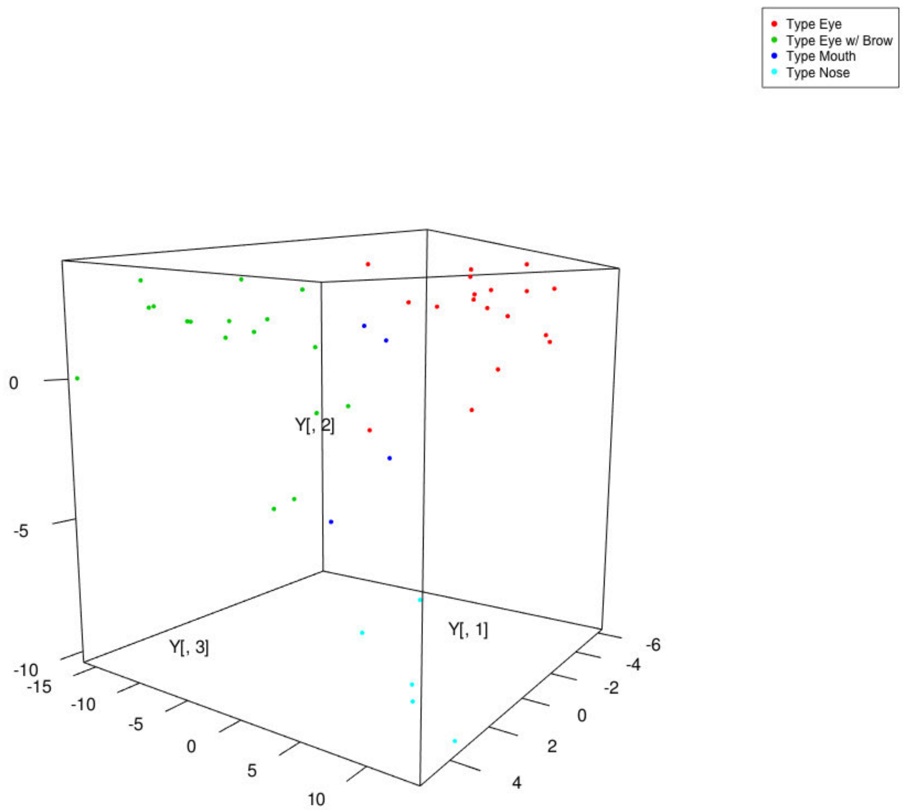

Figure 5. A 3D scatterplot of the projected 43-dimensional facial feature comparisons.

4. CONCLUSION

The same dataset was thus used for two completely different purposes. In this case, the re-use and the re-purposing were planned from the outset and was facilitated by the constant support of different research grants. Results were presented at various international conferences and were also published in due course in traditional and new digital media as well. The simplified models themselves were also made accessible to a large community and anyone interested in the original ones was and is still encouraged to contact the author.

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