COMPUTER BASED FACIAL IMAGE STUDY OF RENAISSANCE ARTWORKS FOR RECOGNIZE LEONARDO AS THEME

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ABSTRACT:

One of the enduring mysteries in the history of the Renaissance is the adult appearance of the archetypical "Renaissance Man," Leonardo da Vinci. His only acknowledged self-portrait is from an advanced age, and various candidate images of younger men are difficult to assess given the absence of documentary evidence. One clue about Leonardo's appearance comes from the remark of the contemporary historian, Vasari, that the sculpture of David by Leonardo's master, Andrea del Verrocchio, was based on the appearance of Leonardo when he was an apprentice. Taking a cue from this statement, we suggest that the more mature sculpture of St. Thomas, also by Verrocchio, might also have been a portrait of Leonardo. We tested the possibility Leonardo was the subject for Verrocchio's sculpture by a novel computational technique for the comparison of three-dimensional facial configurations. Based on quantitative measures of similarities, we also assess whether another pair of candidate two-dimensional images are plausibly attributable as being portraits of Leonardo as a young adult. Our results are consistent with the claim Leonardo is indeed the subject in these works, but we need comparisons with images in a larger corpora of candidate artworks before our results achieve statistical significance.

Keywords: *Face perception, face averaging, attractiveness, vision, aesthetics, natural scenes, artwork*

1. INTRODUCTION

Scholarly opinion varies as to the number of portraits of Leonardo that exist. The red chalk portrait of an old man in the Milan collection of Leonardo's papers (Fig. 1a) is the only one acknowledged by Kenneth Clark, a foremost authority on Renaissance art and Leonardo in particular. Even this identification had been questioned, because the subject appears older than his early sixties, which are the latest that Leonardo could have been served as model in Italy, since he left for France at age 63. Perhaps, then, this is a portrait of his father SerPiero da Vinci or his uncle Francesco. These doubts may be resolved by the fact that Leonardo was described by contemporaries as looking ten years older than his actual age, consistent with the apparent age of the sitter in the portrait. However, Leonardo's appearance when younger is generally regarded as obscure.

Even though only one authoritative portrait is recognized, there is an increasing set of portraits purporting to be of Leonardo that are gradually gaining acceptance among Renaissance art scholars. Restricting consideration to contemporary portraits, just three are known (Fig. 1): one by Leonardo's loyal pupil, Count Francisco Melzi, one by Raphael (who knew the artist from Leonardo's visits to his father Giovanni Sanzio in Urbino), and a newly discovered work by French stained-glass artist Guillaume de Pierre di Marcillat (who had relocated to Arezzo many years earlier,

where in fact he was Giorgio Vasari's master).

Leonardo's appearance in middle age and when young is generally regarded as unknown, although he was described by Vasari1 as of "outstanding physical beauty." Perhaps the most compelling potential portrait is the statue of David by Verrocchio, stated by Vasari to have been modeled on the youthful Leonardo.1 This claim is not often taken too seriously by art historians (such as the above-mentioned Clark and ezzosi), but is given plausibility by the fact that Leonardo was well known as Verrocchio's favorite pupil, and was just the right age for that role.

Taking a cue from this statement, we wondered whether the more mature sculpture of St. Thomas, constructed when Leonardo was Verrocchio's main assistant, could also have been a portrait of Leonardo (with the accompanying Christ as a self-portrait of Verrocchio). The intended interpretation could be that Verrocchio was representing himself as effectively baptizing Leonardo as the avatar of the next generation of artists. Finally,Figure 1. The most securely established contemporary portraits of Leonardo: a) Self-portrait, b) Plato/Leonardo, by Raphael (1510), c) Leonardo, by Guillaume de Pierre di Marcillat (1520), and d) Leonardo, by Francesco Melzi (ca. 1510).there are at least two further portraits which, it is argued, may have Leonardo as their subject. In a video essay, Woldhek2 analyzes 120 depictions of faces in Leonardo's work, and uses an iconographic criterion to exclude most of them, resulting in just three faces that he considers to be plausible self-portraits by Leonardo: the aged self-portrait drawing of Fig. 1a, the

Figure 1. The most securely established contemporary portraits of Leonardo: a) Self-portrait, b) Plato/Leonardo, by Raphael (1510), c) Leonardo, by Guillaume de Pierre di Marcillat (1520), and d) Leonardo, by Francesco Melzi

famous drawing of the Vitruvian man (Fig. 2d) and the Portrait of a Musician (Fig. 2c). This final portrait is puzzling, for a number of reasons.

Originally listed as Portrait of Ludovicoil Moro (Ludovico Sforza, Duke of Milan, who was born in the same year as Leonardo), and as painted by Bernardo Luini (one of Leonardo's closest adherents), the painting has often been attributed as a portrait of Leonardo. A cleaning in 1905 revealed that the sitter is holding a piece of sheet music on which can be seen the letters "CANT...ANG..." (most likely meaning "songs of angels"), which would be inconsistent with the identification of the subject as Duke Ludovico, but would fit with the angelic persona attributed to the young Leonardo. Moreover, Leonardo had a great reputation for being able to play any stringed instrument at first sight. Thus, there seems to be strong evidence supporting the identification of the musician portrait as being of Leonardo, regardless of whether it

was painted by Leonardo himself or by a contemporary.

In this paper we use a statistical method for three-dimensional face shape estimation to quantitatively evaluate the similarity between the faces in the four candidate portraits described above. We show that the face shape estimates from the four portraits cluster well, with smaller intra-class distances than inter-class distances to a set of ten distractor faces.

2. ESTIMATING FACIAL SIMILARITY

Reconstructing three-dimensional face shapes from a single view image is a well-studied problem. In general, single-image shape estimation is an ill-posed problem even when strong assumptions are made about scene geometry, reflectance and camera properties. In the case of paintings, this process is further confounded by potential variations introduced by the artist in their rendition of perspective, shading and illumination,For these reasons, in this paper we neglect photometric cues and reconstruct three-dimensional face shapes using the projected position of fiducial points only. This approach has been shown to perform well on synthetic data. We employ a linear statistical model of three-dimensional face shape (morphable model), learned from a representative sample of human faces. The model is used to constrain the face shape recovery process by transforming it to one of parameter estimation. In contrast to Aldrian and Smith, we use a weak perspective camera model. We find that this is more robust than an affine camera in handling perspective distortions introduced by the artist. Hence, face shape is linear in the morphable model parameters and alternating least squares is used to iteratively solve for pose and shape.

Figure 2. Candidate portraits of a young or middle-aged Leonardo: (a) David (Verrocchio), (b) St. Thomas (Verrocchio), (c) Portrait of a musician (Leonardo), (d) Vitruvian man (Leonardo).

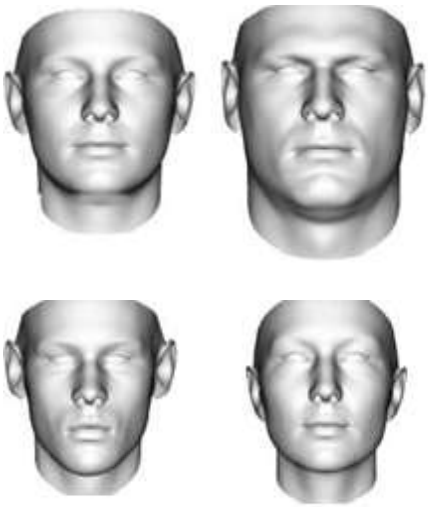

Figure 3. A 3D morphable model of human faces. The top left panel shows the mean face surface.

For robustness, we learn an empirical model of generalization error over the surface of the face. Such a model describes the variance between a true face shape and its best model fit. This approach allows for feature- sensitive weighting of data-closeness errors and allows us to regularize

the optimization problem without manual parameter tuning.

3. General Discussion

We have found that frontal painted portraits show a strong effect of averaging on attractiveness, but that averaged photographed faces are preferred to averaged portraits at all levels of averaging tested. These results suggest that there exist basic differences in aesthetics for the two image classes. We also found that the facial feature arrangements of painted portraits differ signifi¬antly from those of photographed faces, such that preferences for structurally altered portraits peaked nearer to the average portrait configuration than to the average natural face configuration. These results provoke new and interesting questions, which we address below.

3.1. Artistic Canons and Mere Exposure

One explanation of why faces and portraits are different in the respects tested here is that the aesthetic ideal for portraits results from and is reinforced by artistic mnemonics for portraiture (e.g., always place the eyes two-third up in a circle), which do not reflect typical human proportions (see Farkas and Kolar, 1987; Farkas, 1994) but are rather a system of imposed aesthetic ideals (see Vegter and Hage, 2000, for a review). A number of formulae for sketching the face have been used through the ages (see Balas and Sinha, 2007; Gombrich, 1977). Differences in facial feature arrangement (i.e., length and width ratios) could thus be due to agreed standards that have been adopted and passed on from master to student, either by explicit reference to measurable standard, or they could have led to preference through exposure. If a system to construct portraits is explicitly taught as a canon (see Gombrich, 1977, also regarding the golden section) then this canon could provide its own prototype and face- space. This would then create an artificially distinct feature of artistic portraits. Also, the style per se could affect how portraits are perceived. For example, Leder (1996) showed that sensitivity to certain configural features changed when natural portraits were transformed into line drawings of faces. More¬ver, the difference in preference for facial feature arrangement in faces and portraits could ultimately be the result of exposure effects. For example, canon formation has strong historical biases (Cutting, 2003). Accordingly, this exposure could create a norm different from the natural face average. However, even in Western art, artistic canons for face representation show a great deal of variation (Vegter and Hage, 2000), so other explanations may be necessary.

4. Biased Perception

It could also be the case that portraits reflect perceptual biases in face perception. Balas and Sinha (2007) found that humans are poor at guessing from memory the correct placement of eyes and mouth in famous faces (at least in the absence of the external contour of the face). There is also evidence of consistent overestimation of facial feature distances by human observers (Schwaninger et al., 2003), especially eye-mouth distance. We can extrapolate this finding to artistic

portraits: Cohen and Bennett (1997) found that drawing accuracy for faces among novice drawers was predicted not by motor skills or the choice of what features to depict, but rather on their perception of the to-be-drawn face. Our results showing that the ratio of eye-mouth distance is higher for portraits compared to faces would seem to agree notion that these differences are due to misestimation. But if artists consistently misestimated the structure of the face and replicated this in their portraits, we would still expect humans to prefer the average facial feature arrangement of natural faces in portraits, since both photographed faces and faces in portraits would be subject to this perceptual distortion. The idea that misestimation shapes preference is thus a variant of the El Greco fallacy (see Anstis, 2002; Firestone, 2013; Graham and Meng, 2011b).

Therefore, perceptual misestimation of face structure provides at best an incomplete explanation of our findings: the fact that ratio preference in portraits is closer to the empirical average ratios for portraits than to that of photographed faces suggests aesthetic goals may be involved.

4.1 Model Fitting

We use a set of feature points proposed in the anthropometrics literature (Fig. 4).10 This set of canonical points on the face surface were chosen because of their saliency in describing face morphology. For this reason they prove a good choice for reconstruction of faces from sparse data. For fitting to faces in painted works we use the visible subset of these points. For statues we use multiple images, using the visible subset in each image. In both cases, we augment the set of points via an iterative manual process. This allows errors in the reconstruction to be corrected by adding additional feature points where needed (typically along the occluding boundary). For a particular subject, the set of feature points in the kth image is represented by the set of feature point indices Fk. The ith observed two-dimensional image coordinates of a feature point.

	1	2	3	4	5	6	7	8	9	10	11
David	5.58	6.07	6.16	6.77	5.19	5.94	5.06	5.52	5.71	6.90	7.46
Musician	4.09	5.98	5.47	6.92	4.07	5.83	4.22	5.10	5.72	5.01	5.96
St. Thomas	7.34	8.49	8.03	8.19	5.91	7.62	7.00	5.50	6.49	8.34	7.80
Vitruvian man	6.63	6.10	7.73	6.0	6.54	5.38	6.45	6.46	3.33	8.68	8.91

The 3D-3D mean Euclidian errors (mm) between ten distractor faces and face shape

5. EXPERIMENTAL RESULTS

We used our method to construct 3D models of the four candidate portraits shown in Figure 2. The results of this process are shown in Figure 5. The first two columns show the input images used. We extract texture maps from the input images and, in the third column, show this mapped onto the estimated shape, shown in a novel pose. Note that these re-renderings also include frontal illumination showing that the shading (determined by the shape estimate) is in good correspondence with the sampled texture.

We compute mean Euclidian distances between the three-dimensional models from each of the portraits. Because the morphable model is constructed using meshes of known scale, we are able to give Euclidian errors in millimeters. The agreement between the David statue and musician portrait is particularly good, compared to the average distances to distractor faces (different subjects of a similar age and primarily male). The results can be seen in Table. It is clear that the gross facial shape estimated from the portraits are more similar to each other than to any of the distractor faces.

The three-dimensional digital models inferred from the source artworks.

6. CONCLUSIONS

We have addressed the problem of verifying candidate portraits of Leonardo using three-dimensional face es¬timation techniques. We view our work as preliminary but promising, showing that the face shape estimated from the portraits is fairly consistent, and are generally more similar to each other than to "distractor" faces. Any firmer claims would of course need to be based on statistical measures of similarities among a large number representative works.

There are many other avenues for potential future work as well. From a technical standpoint, the algorithms could be improved to address the specific requirements of analyzing artwork. For example, one of the strongest cues, particularly in profile and three-quarter views, is the occluding boundary, which we have not exploited here. In addition, if an estimate could be made of the artist's photometric transformation or style, then it may be possible to exploit texture and shading in the fitting process. Finally, it would be interesting to study the sorts of geometric distortion introduced by artists and due to different facial expression, and to derive a camera model that is capable of capturing this process.

From an art historical perspective, the potential for addressing other questions relating to face analysis is large. As well as comparing and verifying identity, it would be interesting to analyze and modify expression, pose and illumination in portraits. Higher level analysis such as age estimation, and automatic aging of faces might aid in the identification of faces within dated portraits.

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