ANTHROPOLOGIE • LXII/2 • pp. 133–141 • 2024

CICERO MORAES, THIAGO BEAINI, FRANCESCO MARIA GALASSI, VERONICA PAPA, ELENA VAROTTO, MICHAEL EDUARD HABICHT

THE GILDED LADY: A NOVEL APPROACH TO HER FACIAL APPROXIMATION

ABSTRACT: This note presents a novel approach to facial approximation adopting forensic methodologies, that is the process of recreating an individual's facial traits from their osteological remains by combing anatomo-anthropological techniques with artistic rendering. In this article, a facial approximation of the famous mummy known as the "Gilded Lady" is offered based on previously published video material and CT scan data. The process is explained in its main steps. This new facial approximation contributes to the ongoing technical development of the digital applications to the field of bioarchaeology.

KEY WORDS: Anthropology – CT scan – Facial approximation – Gilded Lady – Mummy

INTRODUCTION

"Gilded Lady" is the name given to a mummy belonging to the *Chicago Field Museum* collection, dating from 30 BC to AD 395, at the time when Egypt was a province of the Roman Empire. The embalming process in the Roman period differs from previous periods of Egyptian history, as the technique employed sharply changed: from an era in which mummies were placed in wooden coffins, in the case of the Gilded Lady (henceforth G. L.) her body was preserved only in linen wrappings with the addition of a cardboard mummy mask. Moreover, no hieroglyphs decorated the coffins. The first X-rays were taken on the G. L. in 1986, while subsequently, with the evolution of radiological techniques, it was possible to subject the entire body to computed tomography (CT) scan imaging, hence revealing details of its internal anatomy. This approach allowed researchers to collect data such as sex (female), age at death (40–50 years of age), a potential evidence of tuberculosis, traces of curly hair and details of the embalming process used at the time. Thanks to CT imaging, it was possible to segment the skull data, which allowed a physical facial approximation carried out in

Received 1 November 2023; Received in revised form 17 December 2023; Accepted 3 January 2024. Available online 7 May 2024.

DOI: https://doi.org.10.26720/anthro.24.04.06.1

the study by renowned forensic artist Élisabeth Daynès in 2017 (AMHN 2017a, AMHN 2017b).

MATERIALS AND METHODS

SOFTWARE AND HARDWARE CONCEPTS

Forensic facial approximation (FFA) (Stephan 2015) is an auxiliary recognition technique, which approximates the face from a skull and is used when there is little information to identify an individual based on their remains (Pereira 2015, Ullrich, Stephan 2016, Vaníčková, Bílek 2016, Habicht *et al.* 2018). It should be noted that the technique is not about identification, like that offered by DNA or comparative analysis of dental arches, but rather about recognition that can lead to subsequent identification. For the FFA process to be viable, it is necessary to have the skull to be approximated. Facial approximation in this study followed the same approach described by Moraes (2023) and Abdullah *et al.* (2022), with minor adaptations. The modelling process was carried out in the *Blender 3D* software, running the add-on *OrtogOnBlender* (http://www. ciceromoraes.com.br /doc/pt_br/OrtogOnBlender/index.html) and its submodule *ForensicOnBlender*. The program and add-on are free, open source and multiplatform, so that they can run on Windows (≥ 10), MacOS (≥ BigSur) and Linux (= Ubuntu 20.04).

In the case of the present work, a desktop computer with the following characteristics was used:
Intel Core I9 9900K 3.6 GHZ/16M processor
64 GB of RAM memory
GeForce 8 GB GDDR6 256-bit RTX 2070 GPU
Gigabyte 1151 Z390 motherboard
SSD SATA III 960 GB 2.5"
SSD SATA III 480 GB 2.5"
Water Cooler Masterliquid 240V
Linux 3DCS (https://github.com/cogitas3d/ Linux3 DCS), based on Ubuntu 20.04.

OBTAINING THE SKULL

The data for the three-dimensional skull scan was collected in 2013 from a publicly available video on the website of Washington University in Saint Louis (Purdy, Otten 2014); a few years later the video was no longer present in the original link, but it is possible to find it on the Museum's official Vimeo profile (link: https://vimeo.com/42729358). The video and the data contained therein represent the main reference for this study (Purdy, Otten 2014), as this information was

FIGURE 1: Segmentation of the 3D meshes corresponding to the casing and skull.

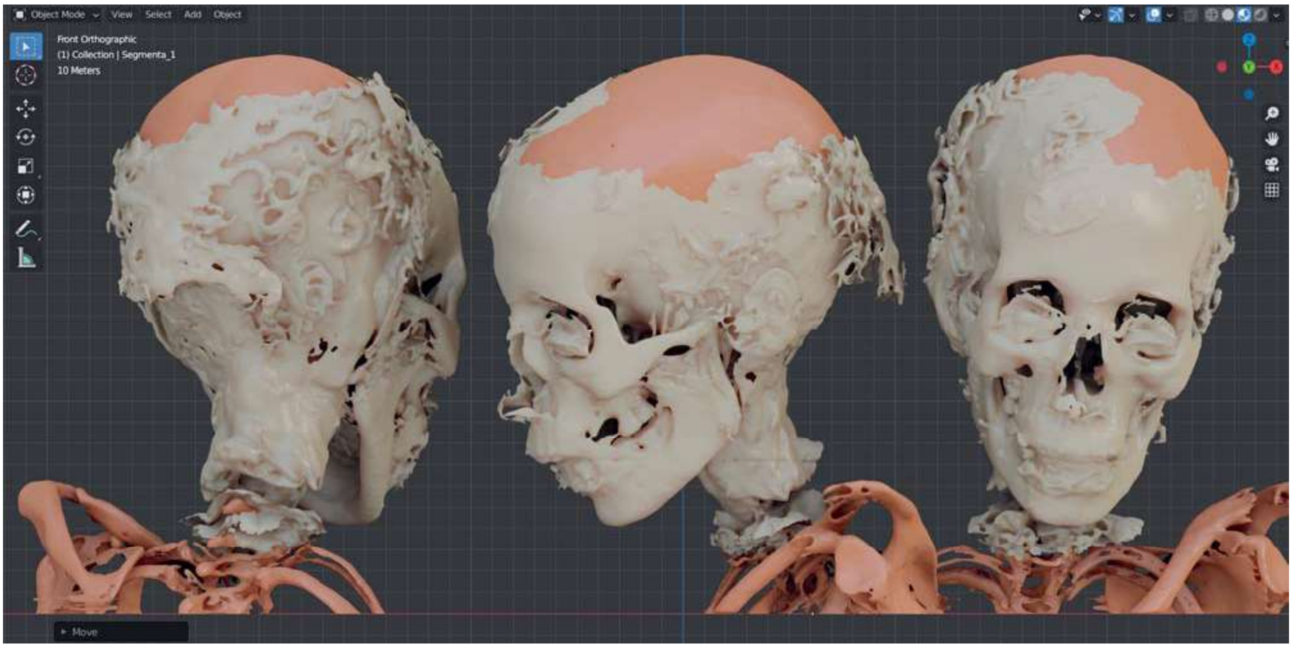

FIGURE 2: Complementary segmentation for nasal projection and hair visualisation.

published through official channels. Moreover, the first author of this article (C. M.) officially informed the *Chicago Field Museum* of the nature and imminence of this study. Although not representing a scientific publication, it contains scientifically relevant information, which *de facto* enters the anthropological debate and can be subjected to further scientific discussion and receive commentary from other scholars in the field. This is the spirit behind our team's approach. Notwithstanding, we aim to declare from the beginning of our investigation that the present technical note is based on the aforementioned material and does not imply the direct access to mummy's remains nor is this study a spin-off project of the 2013 museum-led investigation.

At a given moment of the video, more precisely between 1m 55s and 2m 36s, the sagittal slices of the upper part of the mummy are presented. The captured slices are converted into a sequence of DICOM files, using the OrtogOnBlender add-on (Moraes *et al.* 2021a). The real-scale resizing was carried out thanks to the spatial information (10 cm) contained in the video slice at the bottom in the center, as well as space information on the perpendicular axis of the slices, at the bottom left (it is possible to understand the references when locating the frames in the video available on the Vimeo portal), within the aforementioned range, resulting in models compatible with the real elements (*Figure 1*).

By testing different values of the segmentation factor (Hounsfield scale), it was possible to segment more data related to the nasal bone, as well as visualise part of the curly hair (*Figure 2*). Such information is important for generating a more objective facial approximation, with elements actually present in the tomography.

Moreover, given the good quality of the resulting meshes, it was also possible to segment the endocranium in order to measure its volume and proceed with other related measurements (*Figure 3*).

3D FACIAL APPROXIMATION

The segmented skull was aligned to the Frankfurt horizontal plane. Knowing that the G. L. belongs to the Roman period, a table of soft tissue thickness of living Europeans, measured via ultrasound in mature women aged 40 to 49 years, was used to project the limits of the skin along the skull (De Greef *et al.* 2006) (*Figure 4*).

The lateral nasal projection was performed according to the complementary approach of Moraes *et al.* (2021b) with updated data present in Moraes and Suharschi (2022) (*Figure 5*). A class with the nasal projection process in OrtogOnBlender/ForensicOnBlender using

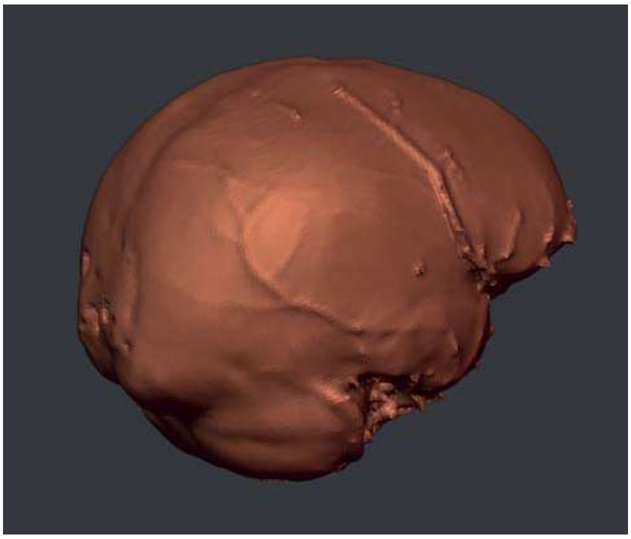

FIGURE 3: Endocranium segmentation.

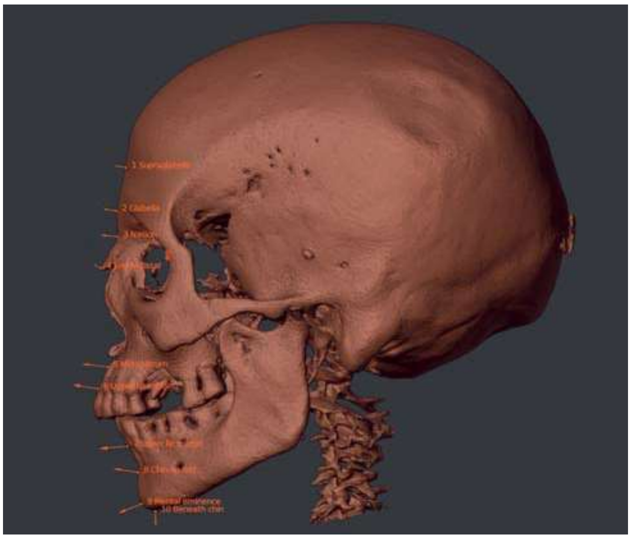

FIGURE 4: Distribution of frontal soft tissue thickness markers.

data from the aforementioned studies can be accessed in the ***Data Statement***.

In addition to the distribution of soft tissue markers and the nasal projection, a series of projections, both of the expected structures for the skull (medial route and proportion) and for the soft tissue (face), were made in OrtogOnBlender/ForensicOnBlender (*Figure 6*). It can be seen that the left orbit is larger than the contralateral one and the face suffers from a significant asymmetry in that region, as this difference can be perceived visually (see the upper limits in green, on the orbits). Regarding the technique used to position graphic elements (green and blue), two classes detailing how projections are made semi-automatically are available in the ***Data Statement*** section.

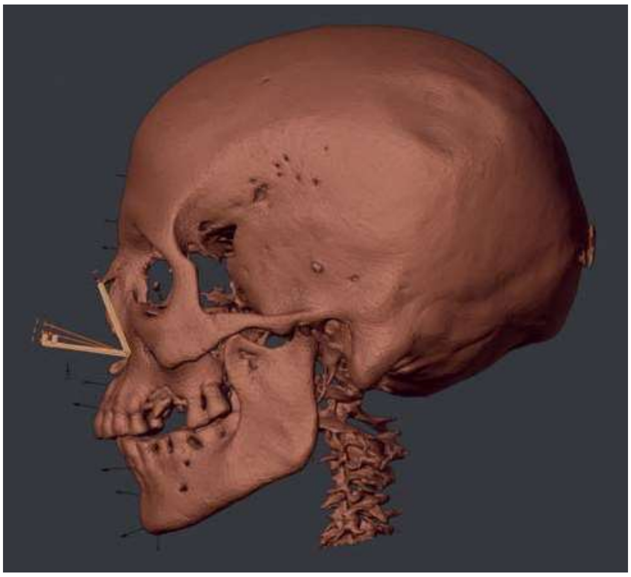

FIGURE 5: Lateral projection of the nose, based on statistical data with proportion and standard deviation.

A complementary projection is made with the anatomical deformation process, where the tomography of a virtual donor is imported and adjusted so that the donor's skull is then the cranium that is approximated, resulting in a face compatible with what it would be like in life (*Figure 7*). A class explaining a practical example of anatomical deformation can be accessed in the ***Data Statement***.

When viewed frontally, it is possible to notice that the anatomical deformation generated a model that corroborates the statistical projections made previously (*Figure 8*). Such deformation was also compatible with soft tissue markers, as can be seen in *Figure 9*.

Once the projections are defined, a "clean" mesh, composed of four-sided faces and coming from another facial approximation, is imported and adjusted to the approximated face. This process avoids the rework of modeling a face from scratch on an existing unpolished mesh (with three-sided faces and nose in the relief). The donor mesh already has a texture (pigmentation) that can be adjusted, as well as hair.

The donor's "clean" mesh is then adjusted to the projections, the hair is configured to match the curly

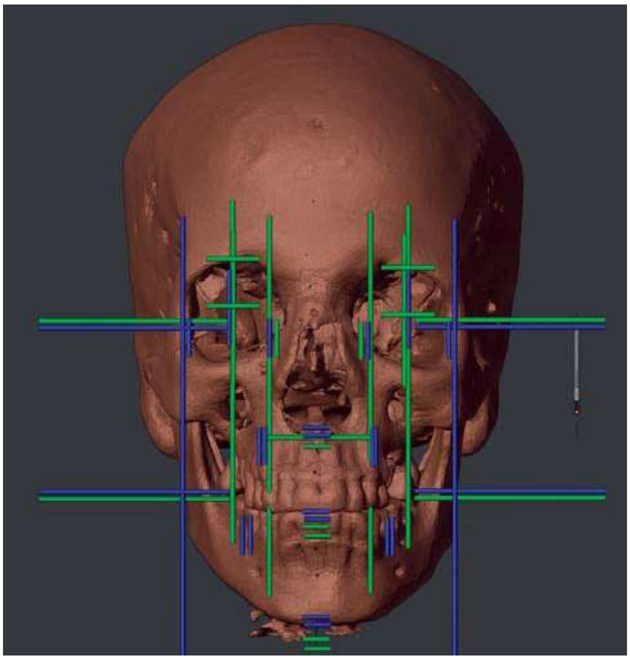

FIGURE 6: Orthographic projections related to averages (in green) and proportions (in blue) of skull and soft tissue structures.

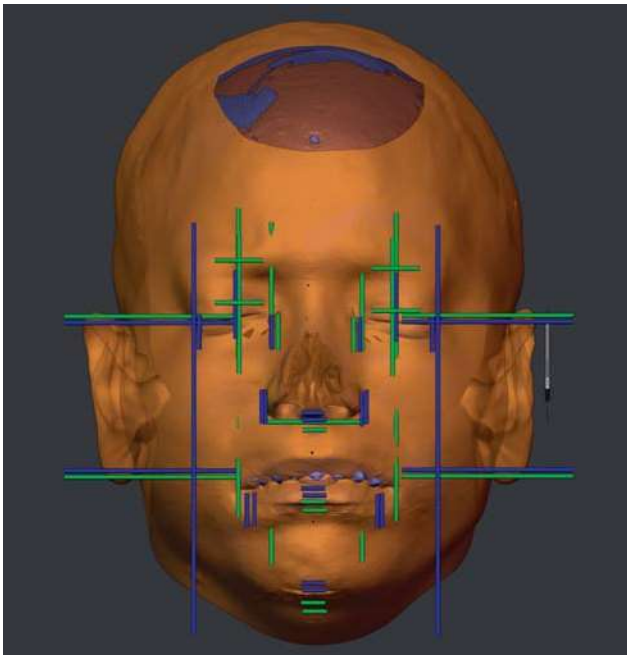

FIGURE 8: Virtual donor mesh already deformed/adjusted to the skull to be approximated, showing compatibility with orthographic projections.

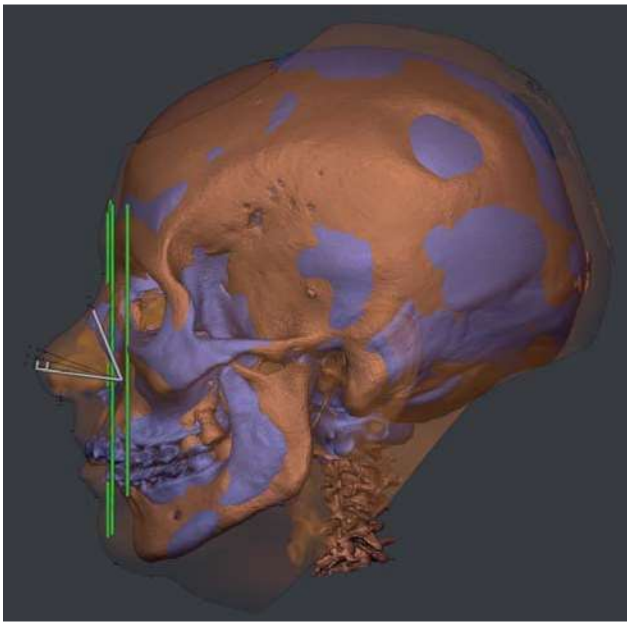

FIGURE 7: Virtual donor mesh, composed of soft tissue and the skull, deformed over the skull to be approximated, and resulting in a face compatible with the G. L.

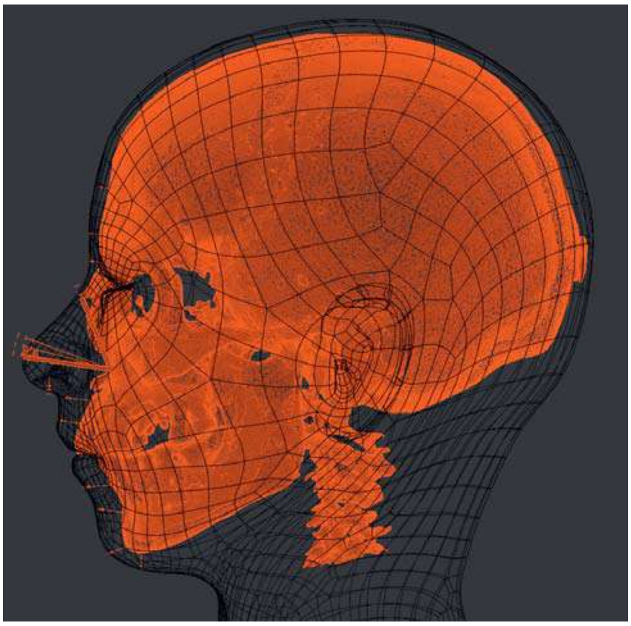

FIGURE 9: Side view of the final mesh over the soft tissue thickness markers and lateral projection of the nose.

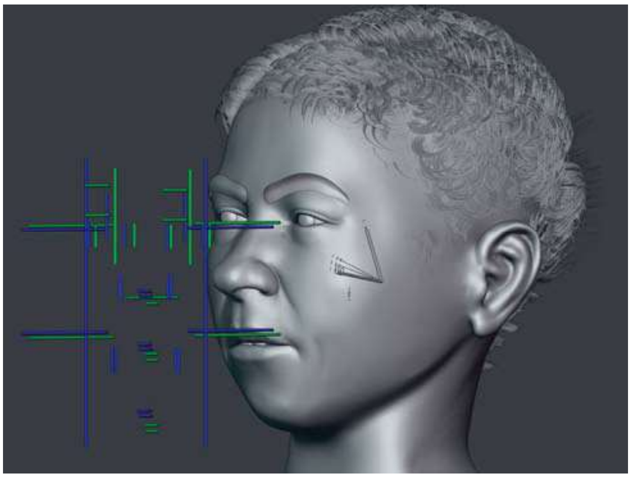

FIGURE 10: Three-quarter view of the final mesh after adjusting facial details by digital sculpting and hair configuration according to data present in the tomography.

FIGURE 11: Three-quarter view of the objective face.

FIGURE 12: Frontal view of the objective face.

FIGURE 13: Profile view of the objective face.

appearance present in the computed tomography (*Figure 10*). The skin pigmentation is carried out in order to provide the makeup of the period, as well as the colouring followed the parameters of the work of Daynes (AMHN 2017a, AMHN 2017b), officially supported by the *Field Museum*, as the publications imply. Examples of videos with skin/scalp pigmentation and hair configuration can be accessed in the ***Data Statement***.

RESULTS AND DISCUSSION

Two approaches related to facial approximation were worked on, one more objective and scientific and the other more subjective and artistic. The scientific approach consisted of a bust equipped with elements closely linked to the statistical aspects of the approximation and since the initial stage of the process was composed only of data collected from tomography and measurements of living individuals and a compatible population, it was possible to generate an anatomically shaped face coherent, including the curly hair, visible on the tomography. The colour chosen was grey scale, avoiding information on skin tone, for which there is no information available (*Figures 11–13*).

The most artistic approach consists of a coloured image (according to data from the work of Daynes) and a wig (*Figures 14–16*). Even though it contains speculative elements about the individual's appearance,

FIGURE 14: Three-quarter view of coloured/ subjective face.

FIGURE 15: Frontal view of coloured/ subjective face.

FIGURE 16: Lateral view of coloured/ subjective face.

as it is a work that will be presented to the general public, it provides the necessary elements for a complete "humanisation".

The endocranium was segmented to assess its volume, using data from the internal mesh of the Gilded Lady's skull, the circumference of the head, from the forensic facial approximation, was also measured. The volumetric survey of the G.L.'s endocranium resulted in ~1280 cm^3, the head circumference in 54.88 cm. When applying the factor of -9.81% to convert the endocranium volume into brain volume (Moraes *et al.* 2023a) 1154 cm^3 is reached, when using the data from Ritchie *et al.* (2018), G.L.'s brain is within the standard deviation for females, whose whose average is 1116 cm^3 ±90. The head circumference, which resulted in 54.88 cm, is very close to the average adult women that is 54.3 cm (±2.3) by Costa *et al.* (2022).

Regarding the limitations of the study, it is a technical note based on a public video originally made available by the University of Washington and the *Field Museum* in Chicago. Despite the sufficient resolution for forensic facial approximation work and data collection such as endocranium volume, finer details can be accessed in the original tomography, which has more data on density structure, as well as a significantly higher resolution than the one resulting from a video that suffered data loss when compressed by the MPEG4 codec.

Further studies can help with technical refinement in order to improve results, making them compatible with the potential structure of the individual in life. Anatomical deformation has been used in numerous studies and tends to corroborate both the thickness of soft tissues and statistical projections (Moraes *et al.* 2023b). Criticism about the donor problem is dispelled not only due to the results of approximations that differ from each other, such as the case of an individual with achondroplasia, where the deformation differed significantly from the donor who was not part of the spectrum (Moraes *et al.* 2024). It was possible to visually perceive an asymmetry of the eye line in the frontal images of the facial approximation.

CONCLUSION

This new approach shows how researchers can produce highly informative facial approximations based on data published in other studies or media outlets, hence contributing to the dissemination of knowledge on mummy research, especially as derived from palaeoradiological studies (Varotto *et al.* 2021, Papa *et al.* 2023).

SUPPLEMENTARY DATA STATEMENT

Mini lecture in Portuguese about what *OrtogOnBlender* is (20 minutes):
https://youtu.be/ungX1_bU1rQ

Introductory class on *ForensicOnBlender* (the Manchester method, different from the one used here, but with some compatible parameters):
https://www.youtube.com/watch?v=PPpgtztomqA

Class on nasal projection:
https://youtu.be/ F205kLQ–Oo

Class 1 of 2 on the projection of facial structures:
https://youtu.be/U6oYkEmfyWo

Class 1 of 2 on the projection of facial structures
https://youtu.be/Vcz2e5uSFX8

Demonstration of facial approximation steps (Manchester method) with example of skin/scalp pigmentation:
https://www.youtube.com/watch?v=5lM8PybpKqY .

Demonstration with example of hair configuration:
https://commons.wikimedia.org/wiki/File:D._Pedro_I__Processo_da_reconstru%C3%A7%C3%A3o_facial_forense.webm

ACKNOWLEDGMENTS

This work is independent, non-commercial and has no official academic link with the *Field Museum*. It is recommended that the reader access the references available in the document, in order to learn about the original and official project, carried out by a team that worked directly on the mortal remains of the Gilded Lady. The objective of this article is merely to show an alternative technical approach, based on free and open-source software, its advantages and limitations. We thank the *Field Museum* and the *American Museum of National History* for making this video and the relevant information on the Gilded Lady publicly available to the public. We also would like to thank Dr. Richard Gravalos for providing the virtual donor's CT scan.

REFERENCES

ABDULLAH J.Y., MORAES C., SAIDIN M., RAJION Z.A., HADI H., SHAHIDAN S., ABDULLAH J. M., 2022: Forensic Facial Approximation of 5000-Year-Old Female Skull from Shell Midden in Guar Kepah, Malaysia. *Applied Sciences* 12, 15: 7871. DOI: 10.3390/app12157871.

AMHN, 2017a: Mummies, meet the Gilded Lady. Rotunda 42,2: 2–5. Online at: https://www.amnh.org/content/download/164374/2639108/file/rotunda-spring-2017.pdf (accessed on 30th October 2023).

AMNH, 2017b: Mummy #30007: The Gilded lady: AMNH. American Museum of Natural History. https://www.amnh.org/explore/news-blogs/on-exhibit-posts/gilded-lady-mummy (accessed on 30th October 2023).

COSTA N. R. da, MANCINE L., SALVINI R., TEIXEIRA J. DE M., RODRIGUEZ R. D., LEITE R. E. P., NASCIMENTO C., PASQUALUCCI C. A., NITRINI R., JACOB-FILHO W., LAFER B., GRINBERG L. T., SUEMOTO C. K., NUNES P. V., 2022: Microcephaly measurement in adults and its association with clinical variables. *Revista de Saúde Pública* 56, 38. DOI: 10.11606/s1518-8787.2022056004175

DE GREEF S., CLAES P., VANDERMEULEN D., MOLLEMANS W., SUETENS P., WILLEMS, G., 2006: Large-scale in-vivo Caucasian facial soft tissue thickness database for craniofacial reconstruction. *Forensic Science International* 159, Supplement: S126–S146. DOI: 10.1016/j.forsciint.2006.02.034

HABICHT M. E., EPPENBERGER P. E., GALASSI F. M., RÜHLI F. J., HENNEBERG M., 2018: Queen Meresankh III – the oldest case of bilateral Silent Sinus Syndrome (c. 2620/10 - 2570 BC)? *Anthropologie (Brno)* 56, 2: 103–113. DOI: 10.26720/anthro.17.09.25.2

MORAES C., 2023: Ava's 3D Digital Facial Close-up (Scotland, ~3806 AP). figshare. https://doi.org/10.6084/M9.FIGSHARE.23560587; http://ortogonline.com/doc/pt_br/OrtogOnLineMag/6/Ava.html

MORAES C., DALLAZEN E., DORNELLES R., DA ROSA E., 2021a: Converting Images to DICOM Files with OrtogOnBlender. figshare. Online at: https://doi.org/10.6084/M9.FIGSHARE.14445366; http://ortogonline.com/doc/pt_br/OrtogOnLineMag/3/ImagemDICOM.html (accessed on 30th October 2023).

MORAES C., SOBRAL D. S., MAMEDE A., BEAINI T. L., 2021b: Complementary Nasal Projection System in Forensic Facial Reconstructions/Approximations. figshare. https://doi.org/10.6084/M9.FIGSHARE.17209379; http://ortogonline.com/doc/pt_br/OrtogOnLineMag/3/NarizProjecao.html (accessed on 30th October 2023).

MORAES C., SUHARSCHI I., 2022: Measuring Facial Orthographic Data in Moldovans and Comparison with Other Populations. figshare. https://doi.org/10.6084/M9.FIGSHARE.20089754; http://ortogonline.com/doc/pt_br/OrtogOnLineMag/4/Moldavos.html; https://bit.ly/3NRw2KW (accessed on 30th October 2023).

MORAES C., HABICHT M. E., GALASSI F. M., VAROTTO E., BEAINI T., 2023a: Pharaoh Tutankhamun: a novel 3D digital facial approximation. *Italian Journal of Anatomy and Embryology* 127, 1: 13–22. DOI: 10.36253/ijae-14514

MORAES C., ŠINDELÁŘ J., GALASSI F. M., BEAINI T. L., 2023b: Ludmila of Bohemia (ca. 860–921): Multidisciplinary considerations on her facial approximation. *Digital Applications in Archeology and Cultural Heritage* 29: e00263). DOI: 10.1016/j.daach.2023.e00263

MORAES C., KRENZ-NIEDBAŁA M., ŁUKASIK S., PRADA C. S., 2024: Forensic facial approximation of an individual with achondroplasia from medieval cemetery in Central Europe. Digital Applications in Archaeology and Cultural Heritage 32: e00301. DOI: 10.1101/2023.08.26.553833

NEUBAUER S., HUBLIN J.-J., GUNZ P., 2018: The evolution of modern human brain shape. *Science Advances* 4, 1: eaao5961. DOI: 10.1126/sciadv.aao5961

PAPA V., VACCAREZZA M., GALASSI F. M., VAROTTO E., 2023: Discover the anatomy of the mummies: how imaging techniques contribute to understanding disease in the past. *Italian Journal of Anatomy and Embryology* 127, 1: 23–34. DOI: 10.36253/ijae-14549

PEREIRA J. G. D., MAGALHÃES L. V., COSTA P. B., SILVA, RHA D. A., 2017: Three-Dimensional Forensic Facial Reconstruction: Manual Technique Vs. Digital Technique. *Revista Brasileira de Odontologia Legal* 4, 2: 46–54. DOI: 10.21117/rbol.v4i2.111

PURDY M. C., OTTEN L., 2014: Three Egyptian mummies receive CT scans. The Source – Washington University in St. Louis. Online at: https://source.wustl.edu/2014/10/three-egyptian-mummies-receive-ct-scans/ (accessed on 30th October 2023).

RITCHIE S. J., COX SR., SHEN B., WHALLEY H. C., LAWRIE S. M., GALE C. R., BASTIN M. E., MCINTOSH A. M., DEARY I. J., 2018: Sex Differences in the Adult Human Brain: Evidence from 5216 UK Biobank Participants. *Cerebral Cortex* 28, 8: 2959–2975. DOI: 10.1093/cercor/bhy109

STEPHAN C. N., 2015: Facial Approximation-From Facial Reconstruction Synonym to Face Prediction Paradigm. *Journal of Forensic Sciences* 60, 3: 566–571. DOI: 10.1111/1556-4029.12732

ULLRICH H., STEPHAN C. N., 2016: Mikhail Mikhaylovich Gerasimov's Authentic Approach to Plastic Facial Reconstruction. *Anthropologie (Brno)* 54, 2: 97–107.

VANÍČKOVÁ E., BÍLEK O., 2016: Anthropological facial reconstruction of the so called "Princess" of Býčí skála. *Anthropologie (Brno)* 54, 3: 299–303.

VAROTTO E., MILITELLO P. M., PLATANIA E., SFERRAZZA P., GALASSI F. M., 2021: Paleopathological study of a podal osteochondroma from the prehistoric Hypogeum of Calaforno (Sicily). *Clinical Anatomy* 34, 1: 19–23. DOI: 10.1002/ca.23603

Cicero Moraes[1], Thiago Beaini[2], Francesco Maria Galassi[3], Veronica Papa[4], Elena Varotto[5*], Michael Habicht[5]

[1] Arc-Team Brazil, Sinop-MT, Brazil
[2] Faculty of Dentistry, Federal University of Uberlândia, Uberlândia-MG
[3] Department of Anthropology, Faculty of Biology and Environmental Protection, University of Lodz, Lodz, Poland
[4] Department of Economics, Law, Cybersecurity, and Sports Sciences, University of Naples "Parthenope", Naples, Italy & School of Science, Engineering and Health, University of Naples "Parthenope", Naples, Italy.
[5] Archaeology, College of Humanities, Art and Social Sciences, Flinders University, Adelaide, SA, Australia
E-mail: elena.varotto@flinders.edu.au

* Corresponding author.