

# 3D virtual facial reconstruction and visualization of ancient Egyptian mummies using spiral CT data

Giuseppe Attardi\*, Marilina Betrò\*\*, Maurizio Forte\*\*\*, Roberto Gori\*\*\*\*, Antonella Guidazzoli\*\*\*\*\*, Silvano Imboden\*, Francesco Mallegni\*\*\*\*\*

\* Dipartimento di Informatica, Università di Pisa

\*\* Dipartimento di Scienze Storiche del Mondo Antico - Egittologia, Università di Pisa

\*\*\* CNR (National Research Council) ITABC (Institute of Technologies Applied to Cultural Heritage)

\*\*\*\* CINECA-VISIT (Centro Interuniversitario di Supercalcolo - Laboratorio di Visualizzazione scientifica), Casalecchio sul Reno - Bologna

\*\*\*\*\* Dipartimento di Scienze Archeologiche - Antropologia, Università di Pisa Institution

Address: Institute of Technology Applied to Cultural Heritage Via Salaria km.29,300

C.P.10 - 00016 Monterotondo St. (Roma)

E-mail: forte@milib.cnr.it

---

## Abstract

The problem of rebuilding a face from human remains has been, until now, especially relevant in the ambit of forensic sciences, where it is obviously oriented toward the identification of otherwise unrecognizable corpses; but its potential interest to archaeologists and anthropologists is not negligible. We present here the preliminary results of a joint research among the University of Pisa, the Visualisation Laboratory of CINECA and the CNR-ITABC (Institute of Technologies Applied to Cultural Heritage, National Research Council, Rome) whose aim is reconstructing, through Spiral Computed Tomography data and virtual modelling techniques (in our case with VTK software), 3-D models of the possible physiognomy of ancient Egyptian mummies. This work is carried out through a multidisciplinary approach, involving different competences: image processing, anthropology, egyptology, computing archaeology.

Main project tasks are: 1. anthropological and egyptological analysis of the head; 2. spiral CT of the head; 3. reconstruction of a 3-D model of the skull generated from CT data processing; 4. reconstruction of soft tissues; 5. application of textures fitting the somatic features.

---

**Keywords:** Facial Reconstruction, Spiral Computed Tomography, 3D visualization, Egyptian mummies.



**Figure 1:** The mummified head in Florence (inv. N .8643) (Soprintendenza Archeologica della Toscana)

## 1. Introduction

The application of radiological techniques to Egyptian mummies has a very old and glorious tradition: the first reports of a radiological investigation of an Egyptian mummy was published by Petrie in 1898 [1]. Since then, radiological techniques were increasingly used and appreciated throughout the 20th century, as a non-invasive mean of investigation: egyptological, anthropological and paleopathological information could be obtained without disturbing the mummy's wrappings. The advent of Computed Tomography in the 1970's marked a further milestone in the history of mummies' investigation: CT numbers allowed a very fine discrimination between materials with different densities, providing an enormous amount of information not only about the mummy and its skeleton, but also about the artifacts buried with the mummy and its coffin [2].

Since the middle of 1980's new developments in computer technology enabled the three-dimensional displaying of axial CT images. The new application, born for clinical use and especially developed for assisting in the planning of surgical operations, was soon extended to mummies examinations and imaging [4]. In the last years, spiral CT has considerably enhanced clinical imaging. The use of this new technique has furtherly widened the range and quality of possible investigations on egyptian mummies.

## 2. The research project

The impulse to our research originated in the observation that most previous work did not deal with the complex problem of repositioning soft tissues on the generated model of the skull. Computerized reconstructions stopped there where soft tissues started. Previous works were not specifically interested in the problem of physiognomic reconstruction, but, when even the interest existed and plastic models of the mummy's head were produced, by stereolithography or by hand, the final moulding of soft tissues was essentially a "human matter", the joint result of the anthropologist's expertise and the artist's sensibility [5]. The need for an automatic, fast and scientifically based program for the reconstructions of mummies (and human remains) features started the collaboration with the Laboratory of Visualisation of CINECA, involved in research both on archaeological visualisation and biomedical imaging.

Focussing on the problem of facial reconstruction, we choosed a mummified head in good condition, from the Egyptian Section of the Archaeological Museum in Florence. The date of its acquisition is 1893; we lack any other reliable information about its provenance. C14 calibrated dating of a sample of the hair gave a probability distribution between 339 b.C. and 201 b.C. [7]. The very good condition of the head, attesting the quality of the embalming process, make us prefer the higher dating.

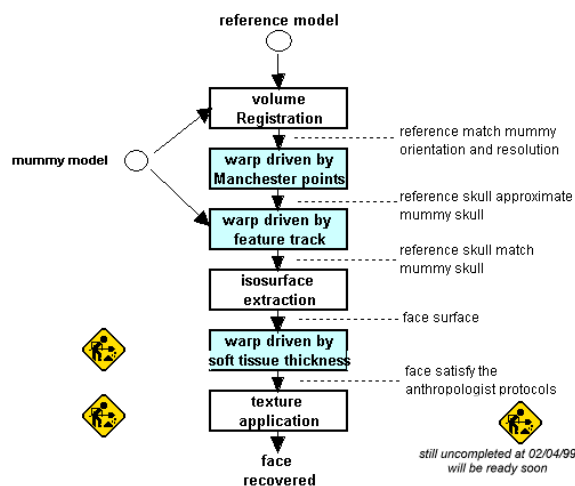


Figure 2 The different steps of soft tissue reconstruction

## Development of the project: soft tissue reconstruction using VTK

After a first part of work, our open problem is to reconstruct the lacking elements of a 3D digital model generated from CT scans applied to mummified cranial remains. As we have described in the previous part of the paper, [8] we work with an hybrid approach [13]; on one hand there is the implementation of the anthropologists' protocol, also known as "Manchester protocol" [15], used in manual reconstruction of remains, in order to control the thickness of soft tissues at specific positions in accord to the measures indicated in [16]. On the other hand warping techniques allow to enhance the mummy model with information coming from another complete CT scanned head of the same race, with the right properties according to anthropological studies, used as reference model.

Our aim is to obtain a perfect match among hard tissues so as to soft tissue of reference model can be used to represent those of the mummy with a good approximation.

Moreover we are developing a tool in order to apply to the model cylindrical textures obtained multiple views of a well suited individual or from other sources as sculptures and paintings.

Software implementation has been designed using Vtk (The Visualization ToolKit), a public domain library for scientific visualization in order to guarantee performance and portability.

## 3. Project Planning

The project involved five different stages:

1. anthropological and egyptological analysis of the head;
2. spiral CT of the head;
3. reconstruction of a 3-D model of the skull generated from CT data processing;
4. reconstruction of soft tissues;
5. application of textures fitting the somatic features.

The different stages are not strictly sequential: as we shall see, spiral CT scanings and, later, their 3-D reconstruction provided new interesting data to the previous phases (anthropological and egyptological investigations).

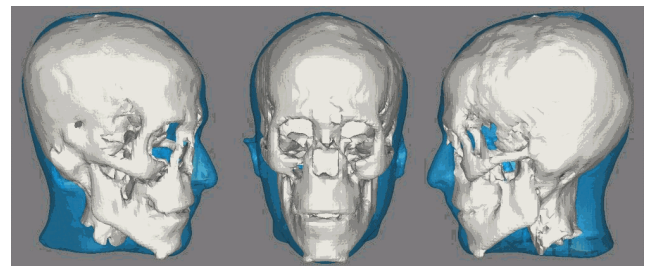


Figure 3. Model skin (blue) and mummy skull (white)



Figure 4. Texturized model of reconstructed soft tissues of the mummy

### Acknowledgements

Special thanks are due to the CINECA-Visit (Visual Information lab), to the Careggi hospital (Florence), to the Pisa Radiology Department at Cisanello and to the Archaeological Museum of Florence for the fundamental support in our research project.

### References

- [1] Petrie W.M.F., Deshasheh, 1897. Fifteenth memoir of the Egypt Exploration Fund. London 1898
- [2] Notman, D., Ancient Scannings: Computed Tomography of Egyptian Mummies, in: "Science in Egyptology. Proceedings of the 'Science in Egyptology Symposia' (ed. R.A. David)", Manchester 1986, 251-320.
- [3] G. Foster, J.E. Connoll, J.Z. Wang, E. Teeter, P.M. Mengoni, Evaluation of an ancient Egyptian Mummy using spiral CT and 3-D reconstructions: interactive display using the World Wide Web, *Radiology* 205(P), 734-35, 1997; on the web: <http://www.rad.rpslmc.edu/rsnamumie/rsnamumie.html>.
- [4] David A.R. (ed.), Proceedings of the "Science in Egyptology Symposia", Part I: Selected papers, 1979. Part II: papers presented 1984, Manchester 1986; Marx M., D'Auria S.H., Three-dimensional CT reconstructions of an ancient human Egyptian mummy, *Amer. J. Roent.* 150, 1988, 147-149; Drenkhahn R., Germer R. (eds.), *Mumie und Computer. Ein multidisziplinäres Forschungsprojekt in Hannover, Sonderausstellung des Kestner-Museums Hannover, 1991*; Baldock C., Hughes S.W., Whittaker D.K. et al., 3-D reconstruction of an ancient Egyptian mummy using x-ray computer tomography, *Journal of the Royal Society of Medicine* 87 (12), 1994 Dec., 806-808 (on the web: <http://www-ipg.umds.ac.uk/MEDPHYS/projects/jen>); G. Foster, J.E. Connoll, J.Z. Wang, E. Teeter, P.M. Mengoni, Evaluation of an ancient Egyptian Mummy using spiral CT and 3-D reconstructions: interactive display using the World Wide Web, *Radiology* 205(P), 734-35, 1997; on the web: <http://www.rad.rpslmc.edu/rsnamumie/rsnamumie.html>.
- [5] See for example the pioneering work of Andreas Pommert and Ulrich Kliegis in: Drenkhahn R., Germer R. (eds.), *Mumie und Computer. Ein multidisziplinäres Forschungsprojekt in Hannover, Sonderausstellung des Kestner-Museums Hannover, 1991*; or the impressive reconstruction of a young child's face in the University of Illinois mummy project: Sarah Wisseman et al., *Imaging the Past...*, in: *Ancient Technologies and Archaeological Materials*, 1994, 217-234 (on the web: <http://www.grad.uiuc.edu/departments/ATAM/imaging.html>). Also in the facial reconstruction of a sailor whose remains were found during the archaeological exploration of the La Salle shipwreck, three-dimensional imaging of the skull was used to generate an exact model of the head through stereolithography; the following stage was the construction -by an artist - of a clay model of the face, based on anthropological tissue measurements.
- A. Ubelaker DH, O'Donnel G, Computer assisted facial reconstruction, *Journal of Forensic Sciences* 1992;37: 155-62
- B. Vanezis P, Blowes RW, Liney AD, Tan AC, Richards R, Neave R, Applications of 3-D computer graphics for facial reconstruction and comparison with sculpting techniques, *Forensic Sci Int* 1989;42: 69-84.
- [6] F. Mallegni, Un volto di gioventù per il principe Uage, in: M. Forte (ed.), *Archeologia. Percorsi virtuali nelle civiltà scomparse*, Milano 1996, 50.
- [7] The analysis was effectuated in the ANSTO Laboratory, Menai, Australia. Ref. Code OZD005.
- [8] Will Schroeder, Ken Martin, Bill Lorensen "The Visualization Toolkit" 2nd.Edition Prentice Hall PTR <http://www.kitware.com>
- [9] Frederic Pighin, Jamie Hecker, DaniLischinski, Richard Szeliski, David H.Salesin "Synthesizing Realistic Facial Expressions from Photographs" SIGGRAPH 98 Proceedings
- [10] B. Lucas and T. Kanade. "Performance of optical flow techniques" proc. DARPA IU Workshop 1981