Actes du XIVème Congrès UISPP, Université de Liège, Belgique, 2-8 septembre 2001

Acts of the XIVth UISPP Congress, University of Liège, Belgium, 2-8 September 2001

ULg
UNIVERSITÉ de Liège

SECTION 1 : THÉORIES ET MÉTHODES / THEORY AND METHOD

Colloque / Symposium 1.7

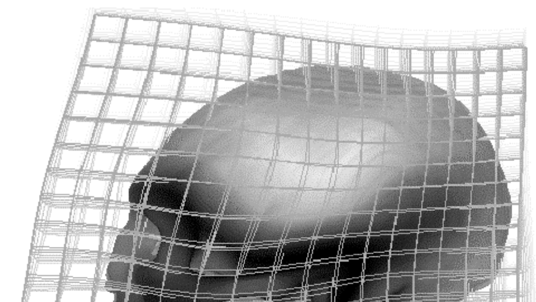
Three-Dimensional Imaging in Paleoanthropology and Prehistoric Archaeology

Edited by

Bertrand Mafart
Hervé Delingette

With the collaboration of

Gérard Subsol



BAR International Series 1049
2002

3D IMAGING IN PALEOANTHROPOLOGY AND PREHISTORIC ARCHEOLOGY: A NEW TOOL FOR OLD SCIENCES OR AN EMERGING SCIENCE?

Bertrand MAFART

The program of the XIVth UISPP Congress included a colloquium entitled "3D Imaging in Paleoanthropology and Prehistoric Archeology" coordinated by Hervé Delingette and myself with the active collaboration of Gérard Subsol. This colloquium provided an unprecedented forum for presentation of high-quality studies and for instructive discussion. I would like to take this opportunity to express my gratitude to the 16 speakers from 9 countries who participated.

I fully expect that there will be a strong demand for these Colloquium Proceedings. This volume constitutes the most extensive collection of data yet published on the topic. In addition to results documenting the value of 3D imaging in a wide range of applications, researchers and students will find a raft of useful information including references, methodologies, and analysis techniques.

Paleoanthropologists and archeologists have always depended on the mind's "natural" 3D imaging ability to analyze material uncovered during excavations. Man's vision is stereoscopic and the neuronal connections in his brain create detailed virtual representations. Mental images are held in memory and can be reproduced verbally or pictorially. The great advantage of computer-based technologies is to automate data collection and image reconstruction. An additional benefit is to allow limitless re-processing and transfer between users.

Despite these advantages many investigators still express reticent to the introduction of 3D imaging and virtual reality techniques. Many still wonder what these techniques actually add to traditional techniques. This question is usually followed by objections that visual examination and description are more precise than digital imaging. The colloquium proceedings contain answers to such questions and objections.

3D images have had a great impact on paleoanthropology. Visualization of intraosseus cavities such as cranial sinuses and semi-circular channels has opened the way to analysis of once invisible structures. Certainly the most clear-cut benefit of 3D imaging techniques involves morphometric analysis. There also is an obvious need for computer assistance spatial analysis of the massive amount of fossil material collected at prehistoric excavation sites. New techniques for automation of 3D data acquisition and spatial positioning hold the promise of allowing reconstitution of the soil of prehistoric settlements and of 3D modeling of the geological and archeological dynamics of the site.

Another reason that 3D imaging that has been beneficial is that it brings together teams of investigators with wide-array of expertise. In paleoanthropology, 3D imaging requires a radiologist for acquisition of scan images, a computer scientists for image processing, and a paleoanthropologist for coordination of anthropological analysis. In prehistoric archaeology, image acquisition often requires a skilful technician able to adapt industrial surface scanning techniques to archeological soils or objects, the services of a computer technician, and the cooperation of the team in charge of the archeological site. The level of technical complexity is such that no investigator can have the full range of competency and yet each must know and understand the problems of the other players. Perhaps for this reason a sort of intellectual alchemy took place between diverse groups of investigators who participated in the colloquium.

Every emerging field has its pioneers. For 3D imaging of hominid fossils it was Franz Zonneveld who started 16 years ago. In his presentation at the colloquium, F. Zonneveld described methodological issues in fossil scanning such as variable degrees of mineralization, inclusion in a matrix, and image resolution. He also reviewed current techniques and above all future perspectives of 3D imaging.

Analysis of sinus cavities and cranial pneumatization has benefited greatly from the advent of three-dimensional reconstruction based on computed tomography data (3D-CT). T. C. Rae and T. Koppe showed how indispensable these techniques have become for the study of non-human primates and mammals in general. Based on their study of paranasal pneumatization in catarrhine primates with special focus on the maxillary sinus, these authors were able to revise previous interpretations of growth and evolution of sinuses in apes and old-world monkeys.

Assessment of endocranial casts is often difficult. The main benefits of 3D imaging are to allow virtual isolation of bones from the geological matrix and production of accurate 3D-hardcopies by stereolithographic modeling. E. Bruner, G. Manzi, and P. Passarello studied the virtual endocast of the Neanderthal Saccopastore 1 specimen and used geometric morphometric analysis to compare results with hominid fossil specimens from the middle and late Pleistocene period. In their conclusion these authors stated that variability in endocranial morphology within the genus Homo appeared to be strongly correlated with the size and expansion of parietal areas.

3D studies have benefited greatly from advances in geometric morphometrics. Up to now, paleoanthropological analysis of the particularly complex morphology of the temporal bone has been difficult. Based on 15 landmarks identified by 3D imaging on the temporal bone, K. Harvati were able to compare differences between Neanderthals and modern humans and between two species of chimpanzees using the Procruste method. Findings indicated that Neanderthals differed more from modern humans than the two chimpanzee species differed from each other.

Medical computed tomography is not the only method allowing 3D image acquisition. M. Friess, L. F. Marcus, D. P. Reddy, and E. Delson used laser surface scanning to assess the relative surface areas of modern hominid skull specimens from various geographical locations and fossilized specimens and to re-appraise theories that variations in the facial morphology of Homo sapiens sapiens are related to cold adaptation. Their findings suggested that facial morphology in Inuit or Neanderthal populations was unrelated to climatic conditions.

Current 3D morphometric techniques do not allow complete analysis of fossil specimens. G. Subsol, B. Mafart, A. Silvestre and M.-A. de Lumley presented a computer-assisted technique that allows 3D visualization and analysis of CT scan images of fossils as well as comparison of these images with each other and with images from modern humans. Homology points between skulls were determined automatically. Future applications in facial reconstruction and three-dimensional morphometry were also presented.

Despite its importance for paleoanatomical analysis of fossil morphology, time is usually factored in after spatial analysis. C.P. Zollikofer and M.S. Ponce De León studied the influence of this veritable “fourth” dimension that has three distinct yet interconnected aspects, namely ontogeny (individual development), phylogeny (speciation) and diagenesis (fossilization). These investigators described several computer-assisted models of geometric morphometric analysis that take into account the effects of these three aspects of the temporal dimension on fossil morphology.

Currently 3D imaging techniques are systematically used in conjunction with traditional analytical methods of fossil analysis. To demonstrate the synergy between these two techniques, J. L. Thompson, A. J. Nelson and B. Illerhaus re-examined the Neanderthal skull of the Moustier 1 adolescent. In addition to studying facial sinuses and determining cranial volume, they were able to obtain a virtual reconstitution of the fossil. Use of the two methods led to a better understanding of the ontogenic and phylogenetic features of this fossil.

3D imaging using computer tomography, magnetic resonance imaging, or surface laser scanning allows “virtual reality” representation of fossils. Specimens can be studied and even reconstructed repeatedly without altering the original. After reviewing the advantages of computerized techniques of data processing and imaging, G. Weber addressed the issue of availability to the scientific community at large. The author advocated creation of global access to a digital 3D-data archive of recent and fossil hominoids.

One of the major challenges of 3D imaging is development of a reliable method of facial reconstruction. Such techniques could be used not only for identification of missing persons from skeletal remains in forensic medicine but also for picturing prehistoric men in archeological studies. G. Odin, G. Quatrehomme, G. Subsol, H. Delingette, B. Mafart and Marie-Antoinette de Lumley compared the results of manual and computerized-assisted techniques for 3D reconstruction of the face of the Tautavel Man. Based on their findings, these investigators concluded that the two techniques are complementary.

Tooth pattern analysis is now within the scope of 3D imaging. O. Kullmer, M. Huck, K. Engel, F. Schrenk and T. Bromage described the use a portable 3D optical topometry system to achieve high-resolution tooth images in an early hominid from Java, Indonesia. The technique allowed virtual modeling of the occlusional surface and morphometric analysis. These data along virtual reconstructions and animations were placed in an image bank.

In addition to static analysis of tooth patterns, 3D imaging allows simulation of dynamic changes due to abrasion. I. L. Gügel and K.-H. Kunzelmann described an experimental simulator designed to quantify dental abrasion resulting during chewing of different cereal species. 3D laser imaging of enamel surfaces were obtained before and after chewing simulation. The findings of this study confirm the efficacy of 3D imaging methods for assessment of the mechanisms underlying dental abrasion.

Archeology is one of the fields offering the widest range of applications for 3D imaging techniques. This point was well illustrated in several colloquiums entitled « Computer Applications and Quantitative Methods in Archaeology ». Prehistorians have already reaped many benefits from computerized data management. Advantages include easier retrieval and processing of data, spatial representation of archeological specimens, and simulation of excavation sites and their geological evolution.

The strengths and weaknesses of current techniques for digital representation of archeological datasets were described by H. Delingette. The main advantages of an entirely digital archeological database are conservation in time and space, mass data handling, and computation of objective measurements. The authors also described current methods of geometric modeling of archeological specimens or sites. A distinction was made between the acquisition, modeling and editing phases of digital processing.

Processing and analysis of archaeological shards is both time-consuming and labor-intensive. R. Sablatnig, S. Tosovic and M. Kampel described a computer-assisted documentation system in which classification and semi-automated reconstruction is based on 3D representations. The ultimate objective of this system will be to automate the tasks of archivage and 3D acquisition for archeologists.

The results of multidisciplinary studies in the Middle Pleistocene cave site in Arago have been placed in a database entitled «Prehistoric and Paleontologic Material» or scanned into a digital library. H. de Lumley, C. Butour, A.-M. Moigne, V. Pois and R. Vaudron presented a 3D reconstruction of the prehistoric settlement and a simulation of the geodynamic evolution of quaternary filling of the Caune de l'Arago.

The studies presented at this colloquium show that 3D imaging techniques do not compete with or detract from other methods. As their availability and power grows, computerized systems based on technologies with capabilities far beyond those of the human eye (e.g. industrial scanners and high-resolution laser) will become indispensable tools alongside classic anatomical and morphological analysis. This technology should not be considered as an emerging science in itself but rather as a powerful new multidisciplinary tool to assist paleoanthropological and archeological studies.

Development of 3D imaging for paleoanthropology and prehistoric archeology will be as great over the next decade as that of the Internet for communications was over the last ten years. Computer systems allow limitless storage, analysis, and exchange of data. Geometric morphometry with 3D images will demonstrate the full potential of analysis. This technology is fast becoming an integral part of the scientific methodology both for research and reporting. Soon no investigator will be able to avoid using these techniques in his work. Research centers need to have a clear policy to promote and encourage this development for the greater benefit of pre-historical and protohistoric sciences.

Adress of the author:

Laboratoire d'Anthropologie
Faculté de Médecine secteur Nord
Boulevard Pierre Dramard
13916 Marseille Cedex 20
bmafart@aol.com