The FOVEA Project: A New Look at Human Past

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Abstract. Use of virtual imagery is getting more and more predominant in the study of fossil remains. The FOVEA project (Virtual Excavation of Paleo-Anthropological Environment) proposes to build a 3D virtual model of a prehistoric site that is exhaustive (i.e. including the geology, the artefacts and the fossils), interactive and that will be made available to the scientific community via Internet. We describe a preliminary part of this project, which consists in the reconstitution of the oldest Frenchman, Tautavel Man, by assembling and deforming the 3D virtual models of the fossil skull fragments.

Keywords: Palaeontology; Virtual fossil reconstruction; Virtual reality; Tautavel Man; Homo erectus

1. Introduction

Each day, digital images and three-dimensional representations are getting more and more predominant in our representation of the future, in the present life, but also in the study of the past. In particular, archaeology as well as palaeontology [1], and through them, the study of the fauna [2], of typology [3], sedimentology [4] and paleoanthropology [5] are from now on fields of application of digital imagery… but so far, mostly in a dissociated way. There are very few links between as well as within these fields. Moreover, very often the collected data are not exploitable, or with difficulty, by others than those who obtained them [6]. Hence the understanding of the past as well as the preservation of its traces is limited.

The two-years FOVEA project (Virtual Excavations of Paleo-Anthropological Environment), established within the framework of the CNRS (French Center of Scientific Research), was set up so as to gather and then coordinate these disciplines in order to better collect, exploit, archive and share data resulting from an excavation.

After having introduced the general research orientations of this project, we will present a concrete example of using virtual reality technologies to safeguard the past: the reconstitution of the skull of the Tautavel Man, the "Oldest Frenchman" (- 450,000 years old).

2. Overall presentation of the FOVEA project

FOVEA aims to model in 3 dimensions a prehistoric excavation site (Caune of Arago, Tautavel, France) through all its components.

The first axis will refer to the reconstitution of the subsoil and its various geological layers. The user must be able not only to visualize the layers but also to manipulate interactively them, for example to pile up or to deform layers in order to compensate for the geological deformations that have taken place after the deposition. Such a modelling must also take into account the different physical behaviour of the layers (sand, rocks…)**.**

The second axis will consist in a virtual study of these layers, which must give access to the found artefacts (bones, tools, installations, traces of fire). First, it will be necessary to enter all the remains (tools, bones…) into a database, from which the choice of a reference will give us access to the object type, to the 3D co-ordinates of the object (x, y, z), but also to its dimensions (length, width, thickness), as well as to its orientation (geographical and vertical). This database, connected to a 3D dynamic representation of the soil, will thus make it possible to interactively highlight grounds of habitats, specific workshops (butchery, tool cutting, camp sites…) or specifically locate the artefacts by category, size or orientation. Another point will consist in acquiring a 3D representation of these objects, with the aim of indexing or refitting them automatically, after having carried out an automatic extraction of shape or texture attributes.

The last axis is the 3D modelling of the fossils. From digital slices (obtained for example by a CT-scanner), it is possible to reconstitute 3D virtual models and then to study human remains without fear of deterioration, to visualize easily the internal structures, to carry out morphometric analyses, or to test hypotheses for compensating post-mortem deformations. We show in the next section an example of using 3D models of fossil skull fragments to propose a new reconstitution of the complete skull.

3. A first application: using 3D models to suggest a new reconstruction of the Tautavel Man

3.1. The fossils and the manual reconstruction

In 1971, a human face was discovered in the “Caune de l’Arago”, a cave located at Tautavel, France, in the layer “G” dated to 450,000 years BP [7; 8]. It was the 21st human remains found in this place, therefore called “Arago 21”. In 1980 was discovered an incomplete right parietal bone, “Arago 47”, which could be adjusted with the face. Those two bones were called “Tautavel Man”, who was identified as a *Homo heidelbergensis*. The minute study of isolated small bone fragments in the palaeontology laboratory led to the discovery of two other parietal fragments, “Arago 47A” and “Arago 3A” corresponding to the right and left sides of the bregma area of the same individual.

Arago 21 is a complete face, including malar, maxillary, nose and frontal bones (see Figure 1, left). There are many deformations, structural and superficial, due to a lateral pressure after

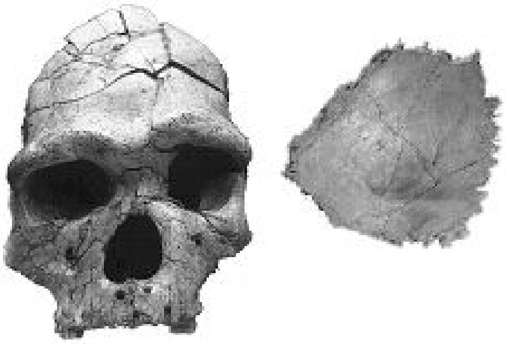

Figure 1: Arago 21 and Arago 47.

Figure 2: Manual reconstruction of a prehistoric skull [9].

depositing and the most distorted part is the left side of the face. The external surface of the right malar bone is deep, without internal deformations. The right parietal bone, Arago 47 is incomplete (see Figure 1, right). The posterior and temporal parts are totally preserved with a large angular torus and a portion of the sagittal suture. We can notice 2 mm of coronal suture and it is the principal clue that allows us to say that it is the same individual than Arago 21. Arago 47A and 3A are two parietal bregma fragments fitting together with the frontal, that allows us to reconstruct the anterior part of the sagittal suture.

A first reconstruction of the overall skull was performed in 1981 by M.-A., H. de Lumley and R. David. They manipulated manually the fragments (see Figure 2) and adjust them with parts of mouldings of other skulls (Swanscombe for the occipital part, Sangiran 17 for the temporal part). Nevertheless, this reconstruction have to be improved. The posterior curvature between the two parietals (original and reconstructed) does not correspond to an anatomical structure, creating an unusual protuberance. The reconstructed face is distorted, not balanced, still asymmetric (different orbital cavities, slantwise nose…). The sagittal suture is not in line with the lateral curvature and some anthropological landmarks are not aligned. Finally, the asterion-lambda-asterion angle is too short for a Middle Pleistocene Hominid. The reconstruction looks more like that of the present *Homo sapiens*, and some anatomical characteristics are incompatible with *Homo heidelbergensis* (i.e. torus angularis, parietal thickness, supra-orbital torus, prognathism).

3.2. A virtual reconstitution based on 3D models

The fossil skull is placed into the Computer Tomography device that gives, in a few minutes, a series of 180 digital images representing the successive slices of the anatomical structure (see Figure 3). These images are of a resolution of 512 by 512 pixels, which are coded in several thousands of gray levels. They are then “stacked” in order to build up a three-dimensional image. CT-Scan devices that are routinely used in medical radiology have a resolution of one or half millimeter whereas special industrial micro-scanners can reach up to a resolution of one hundred microns [10].

Some 3D image processing algorithms developed for medical imaging or Computer Assisted Design are then applied to extract the surface of the structure from the 3D image and to display it, from any point of view, on the screen of a computer. Such programs allow also one to manipulate

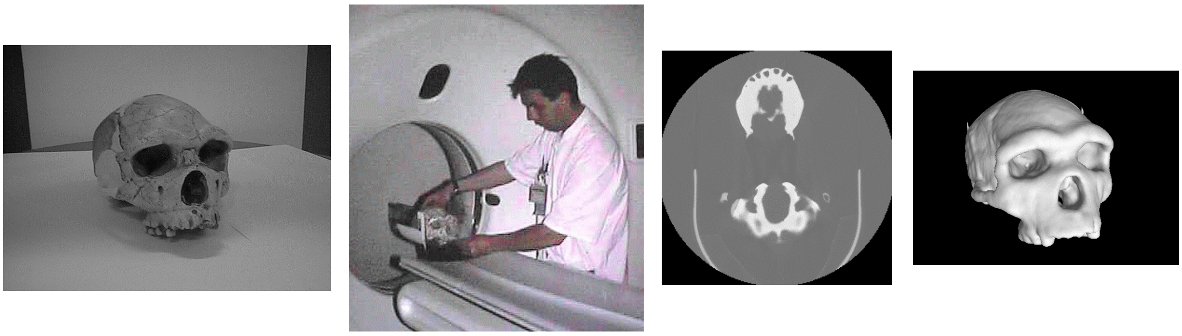

Figure 3: From the real skull of the Tautavel Man to a virtual 3D model [15; 16].

the 3D models of the fragments in order to reconstruct a complete skull [10; 11; 12; 13]. Thus, for our virtual reconstruction, we have used Materialise software (*Magics 7.5* and *Mimics 7.1 [14]*) in collaboration with Initial Society and P. Corbex.

We have taken into consideration the different points of view [17; 18; 19] about the reconstruction of the skull of the Tautavel Man and we have then used external anatomical features (parietal line, coronal suture) to position the bone fragments on the computer screen.

First, we were looking to obtain a more accurate version of face: we corrected the frontal bone (width, positioning of fragments, curvature). Thanks to the deformation tool that allows the user to deform locally the shape of the model mesh, we modified the “nose” in order to have a less distorted nasal cavity and a smaller rise of the right malar bone. Then, we chose to keep only the right side of the face, which is the less deformed and we “mirror” it in order to obtain a symmetric face. These manipulations corrected the inferred effects of general deformation due to the compression of the face that occurred during fossilization.

In the second place, we had to position the parietal bone (Arago 47): we used the portion of the coronal suture to connect the parietal and the frontal bones, like in the former reconstruction. Nevertheless, we “rose” the parietal right posterior part, using measurements obtained by preliminary work on a moulding. It allowed us to test different arrangements. After that, we did a reconstruction of the midvault by mirroring the right parietal bone. Only for comparison (see Figure 4), we adjusted on our rebuilding the occipital of Swanscombe, but not the two-bregma fragments, which were not scanned at that time.

We can see the new reconstruction in Figure 4. We observe a growth of the missing pterion part and a reduction of the missing sagittal suture. In the lateral and the sagittal view, we can see the connection of parietal and the frontal bone, with a continuity of the parietal line. There is no more break anymore between the face and the parietal in superior view (Figure 4, on the left). The sagittal suture is now straight, without curvature. The midvault is more rounded in frontal view. The asterion-lambda-asterion angle is growing too. The former reconstruction gave a value of 73° for asterion-lambda-asterion. The new value is 90,7°. For comparison, the average of *Homo sapiens* is 85° and, for *Homo neanderthalensis*, it varies between 70 and 99° and between 87 and 108° for *Homo erectus* [20]. This new measurement corresponds more to an old hominid.

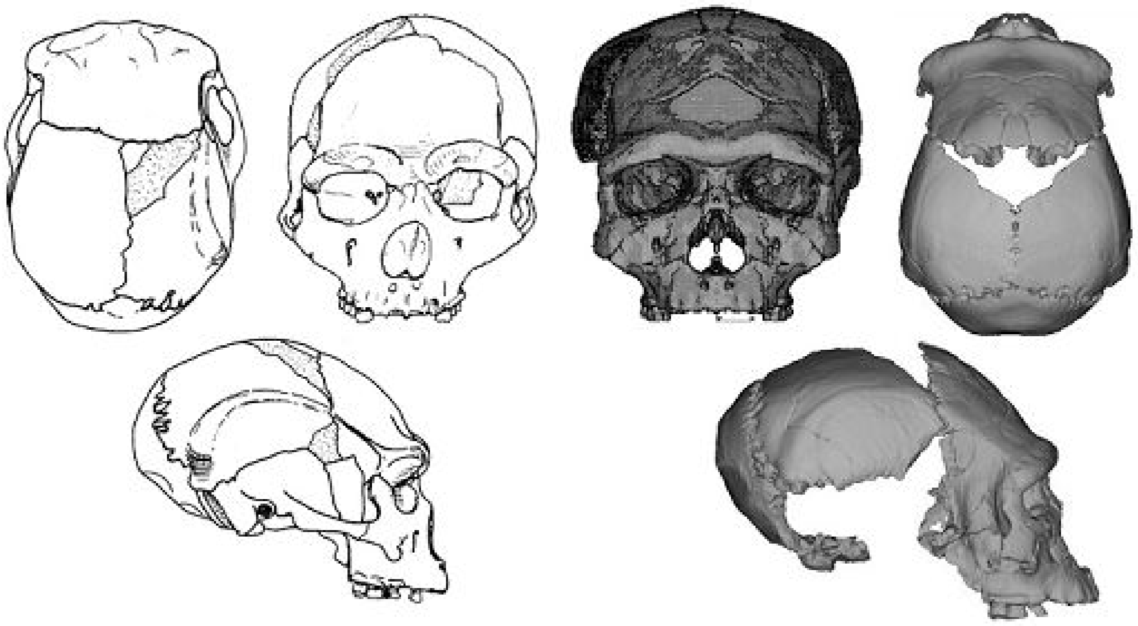

Figure 4: Different views of former (left) and newer reconstitutions (right) of the Tautavel Man. We can see in the newer reconstitution a better continuity between the facial and the parietal fragments.

This work on the Tautavel remains will be finished with the addition of the two-bregma fragments. With 3D image processing software, we will be able to correct definitively and precisely the curvature of the superior part of the frontal bone and the coronal suture. Our work will consist in levelling out the small excrescences created by frontal deformation. After that, we will have a consistent sagittal outline from the rhinion and the nasion to the bregma, beginning of sagittal suture, a small gap (2 cm) and the rest of the sagittal suture to the lambda (Figure 4, right).

This new reconstruction leads to a new paleo-anthropological interpretation. Now, the anatomical characters look more archaic than later Middle Pleistocene *Homo erectus* and *Homo heidelbergensis*. Comparison with the skulls of other fossil men allows us to place this reconstitution closer to an older skull, the one from Ceprano, *Homo cepranensis* [21]. Our new reconstruction shows anatomically many similarities: a broad nasal bone, a torsion of the supraorbital torus, a bilateral discontinuity of the supratoral sulcus, a pronounced postorbital constriction, a frontal keel, a flattened parietal, a maximum breadth across a prominent angular torus, and a low cranial vault. The dimensions of temporal bone of the Ceprano Man correspond to the gap in the Tautavel Man. A comparison with this man, who died 900,000 or 800,000 years B.P. [21], points out the archaic characteristics of Arago 21-47 [22].

4. Discussion and conclusion

This example shows how it is possible to go from a deformed, fragile, difficult to handle fossil to a virtual reconstruction easy to manipulate and study. The power of 3D image processing and modelling tools allow to perform manipulations that are very difficult (mirroring) or even impossible (local deformation) to do on the mouldings which are used in manual reconstruction.

Moreover, such tools open new fields of research, in particular to compute and process 3D morphometric measurements [15; 23]. Another technology that can also enable us to manipulate these reconstructions concretely is stereolithography [24], that synthesize a model in resin based on the virtual model.

The presented work is the first result obtained within the FOVEA Project. We hope to be able to present in two years some Virtual Reality tools that give an interactive and global 3D view of an excavation in real time. Until now, the excavation of a site was equivalent to its destruction, to a representation of the environment in texts, and to the storage of the artefacts in drawers, accessible only to a minority. From now on, these fossils records will also be represented in their contexts, preserved on hard disks and Web servers and accessible to all. Such a site, although disappeared in real life, will constitute a virtual heritage to new generations of diggers who will be able to study it from any location in the world.

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