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Technical Note

Photogrammetric 3D skull/photo superimposition: A pilot study

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ABSTRACT

The identification of bodies through the examination of skeletal remains holds a prominent place in the field of forensic investigations. Technological advancements in 3D facial acquisition techniques have led to the proposal of a new body identification technique that involves a combination of craniofacial superimposition and photogrammetry. The aim of this study was to test the method by superimposing various computerized 3D images of skulls onto various photographs of missing people taken while they were still alive in cases when there was a suspicion that the skulls in question belonged to them. The technique is divided into four phases: preparatory phase, 3d acquisition phase, superimposition phase, and metric image analysis 3d.

The actual superimposition of the images was carried out in the fourth step. and was done so by comparing the skull images with the selected photos.

Using a specific software, the two images (i.e. the 3D avatar and the photo of the missing person) were superimposed. Cross-comparisons of 5 skulls discovered in a mass grave, and of 2 skulls retrieved in the crawlspace of a house were performed. The morphologyc phase reveals a full overlap between skulls and photos of disappeared persons. Metric phase reveals that correlation coefficients of this values, higher than 0.998–0,997 allow to confirm identification hypothesis.

1. Introduction

The identification of bodies through the examination of skeletal remains holds a prominent place in the field of forensic investigations because the main objective of such inquiries is to establish the identity of the person to whom the remains belong. The use of DNA analysis in identifying human remains has become much more widespread in recent years. However, it is not always possible to utilize DNA due to the fact that under certain circumstances it may be subject to so much degeneration that it makes it impossible to extract it. This is particularly true in situations where the remains are extremely charred but the skull is sufficiently intact or in an advanced state of decomposition.

It is generally appropriate to first turn to traditional anthropological and odontological techniques in cases involving body identification [1–6]. First an initial screening is carried out to establish the sex, age, height, and ancestry of the subject. Following this, if there is any suspicion that the remains belong to a presumably missing person, ante-mortem data, such as dental records, are compared with the aim of identifying or excluding the subject, when such information is available. This procedure is quickly and easily performed. It is not always possible, however, to have access to radiographic documentation that might prove useful in body identification, and so it becomes necessary to turn to alternative techniques. When medical documents or other sources for a personal identification are missing, “facial reconstruction” could be performed. This procedure involves the manual or computerized re-creation of the soft tissue of the unidentified subject’s face in order to create an image that approximates the subject when he was still alive. At the very least, such images can be invaluable in refreshing the memories of relatives and friends. This is not a bona fide identification method, per se, because the face is only partially influenced by underlying bone structure.

Another technique that has been applied in the past was craniofacial superimposition. For example an X-ray method used a prism, a photo of a missing person and an X-ray which formed the three vertices of a triangle. The prism was the right angle and two cameras shoot images reflected by the prism. The superimposition was carried out by a video mixer. Such images are typically much easier to obtain than medical documentation.

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Technological advancements in 3D facial acquisition techniques have led to the proposal of a new body identification technique [7–14] that involves a combination of craniofacial superimposition and photogrammetry, which is a method that utilizes photographic images of an object in order to obtain its exact dimensions. In order to create a relief image of an object, it is necessary to obtain the spatial position of all points of interest. This is made possible through photogrammetry, where the relief image is indirectly obtained using photographs.

The technique proposed here allows for the creation of a computerized, three-dimensional model of the skull (i.e. avatar) onto which an image of the subject in question is electronically superimposed. This makes it possible to create a computerized three-dimensional model (CAD) of the skull by way of stereophotogrammetry, which involves the collection of a number photographs taken from various angles. The resulting 3D avatar can then be rotated and orientated in space, depending on the needs of the user, so that it may be superimposed onto an ante-mortem photo of the missing person. Just as in facial reconstruction, this method is based on the principle that the bones of the face act as scaffolding for soft tissue, whose characteristics depend on underlying bone structure. In this case, however, there is the added advantage of already having a photo of the subject for comparison. And so, the hypothesis of superimposing a photogrammetrically generated image of the skull onto an ante-mortem photo of the subject's face was established.

The aim of this study was to test the method by superimposing various computerized 3D images of skulls onto various photographs of missing people taken while they were still alive in cases when there was a suspicion that the skulls in question belonged to them.

2. Materials and methods

The study presented here is based on the identification of 13 skulls, five of which were female, and eight male. Sex on skulls was established using the morphological method proposed by Acsadi and Nemeskeri [15] which is based on the analysis of morphological characters of the skull, assigning to each a positive value to the negative characters of the male and female type for those of type: the comparative analysis of these values are finally calculates a sexualization coefficient (M).

In this study, 5 of the 13 skulls were discovered in a mass grave; 2 in a crawlspace of a house, and 6 were discovered in the open countryside. Each skull was assigned an identification number. The technique was carried out in 4 distinct steps. In the first one, high quality photos, carried out with a standardized subject-to-camera distance, in which the entire craniomaxillofacial area was visible, were selected. These images allowed the anthropometric reference points to be unequivocally established (Fig. 1).

After selecting adequate images for each of the skulls, four reference points, which corresponded to the craniometric points, were identified according to the following anatomical criteria:

1. **The glabella:** which comprises the frontal bone above the nasofrontal suture, located between the superciliary ridges. On the face, it is seen as the cutaneous area between the nasal root and the superciliary ridges.
2. **The left and right ectocanthion point:** The point of intersection between upper and lower eyelids; it corresponds to the orbit.
3. **The nasospinale point:** the midpoint of the base of the anterior nasal spine. On the face it is found between labial philtrum and the columella.

The second step involved the acquisition of data for creating the 3D avatar of the skull. This was carried out by way of a stereophotogammertric technique, or rather, the synchronized snapping of multiple, calibrated photographic cameras precisely positioned so as to produce a series photograms of the skull taken from various angles [16–20]. This particular 3D photogrammetric method set-up was designed and implemented at the Laboratory of Rapid Prototyping and Reverse Engineering at Polytechnic University of Bari (Italy). A Canon D600 photographic camera, stabilized with a tripod, was used and was able to generate between 35–40 photograms for each skull (Fig. 2).

Fig. 1. The missing person photo with the anthropometric reference points.

The 3D information was obtained through the acquisition and comparison of a number of specific photographic images using the principles of triangulation. The photographs must be taken from at least two different positions, so that when virtual lines are drawn from each of the cameras to the object, in this case the skull, it is possible to define the 3D coordinates of the points of interest and, therefore, the shape and size of the object. A 3D model of the skull was then obtained in the form of a point cloud, which provides a list of points described according to their spatial coordinates. Through the connection and recognition of the characteristics that bind these 3D points in the cloud, a mesh was created, (i.e., a reconstruction of the skull consisting of tiny polygons: usually triangles) [21–26]. A computer equipped with photogrammetric software (Photomodeler) was then used to process the images [27–

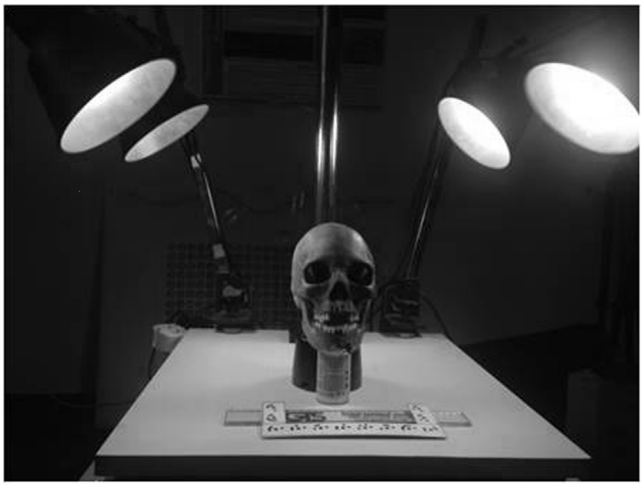

Fig. 2. The acquisition of data for creating the 3D avatar of the skull by the synchronized snapping of multiple, calibrated photographic cameras precisely positioned so as to produce a series photograms of the skull taken from various angles.