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CASE REPORT

# Superimposition technique for skull identification with Afloat® software

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**Abstract** The craniofacial superimposition technique is still an important way of identifying skulls when there is no reference sample for a forensic DNA analysis, when DNA typing from remaining tissue samples has failed, or when antemortem dental records are not available. Through the widespread use of digital photography, the probability of portrait photographs of the missing person being available for comparison is reasonably high. We present a superimposition technique that is inexpensive, since it uses a free software tool compatible with the soft-and hardware components already being used in many facilities. Into the bargain, this technique yields high-quality results.

**Keywords** Superimposition · Skull identification · Afloat · Live view · Forensic anthropology

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## Introduction

When the skull of an unknown person is found, the methods available for establishing identity are forensic odontostomatology [16, 20], molecular genetics [15], and craniofacial superimposition [17]. The aim is to establish whether the skull could be that of a person reported missing. To that end, reference material dating from the lifetime of the missing person is gathered. The craniofacial superimposition technique requires a portrait photograph of the missing person. In this age of digital photography [23], with the resultant mass of photos taken of individual people, this prerequisite—the availability of a current, usable photo—can usually be fulfilled without problem, depending, of course, on the period of time that has elapsed between the missing report and the finding of the skull.

The different techniques of superimposing a portrait photo on a skull have changed, or have been modified, in the course of time, and with the advent of new technologies.

Obtaining an image of the skull which is correctly aligned to match the orientation of the face in the antemortem, portrait photograph is essential for the craniofacial superimposition technique. In 1959, Grüner and Reinhard presented a "photographic method for skull identification" that guaranteed correct skull alignment through the use of a so-called optical bank, in which superimposition of skull and photograph was achieved through double exposure of a 35-mm film [7]. In the course of time, this method was modified so that less tools were required, and the optical bank was no longer necessary [8].

Helmer and Grüner [10] used a video image mixing device to further modify the method. Images of both the skull and the photograph were acquired by two separate TV cameras and were then displayed on a TV monitor with the aid of a video mixing device. For the first time, this allowed the alignment of the skull with the photograph in live view [11]. The skull–portrait superimposition displayed on the TV screen was then documented by photographing the image off the monitor.

This technique was still being used in a publication from 2008 [6]. The expensive TV cameras had, however, been replaced by two commercially available video cameras, and the analog camera had been replaced by a computer with image capturing software.

Once a photograph of the aligned skull has been acquired, superimposition can be performed digitally with modern image editing software [21]. However, to date, it was not possible to align the skull with a super-projected image of the portrait photo in live view. At best, it was possible to tile the live view image of the skull next to the portrait image on the same screen.

Other approaches first digitized the skull in 3D to then virtually align it to the portrait photo [3, 5]. There has also been work on algorithms that would enable software to automatically align the images [13].

In a direct superimposition of skull and portrait, significant obvious disparities can lead to an exclusion of identity. In cases where identity is to be established, tissue markers with the expected average soft tissue depth have to be glued to the "landmark" sites on the skull; these tissue markers then also have to align with the contours of the face in the portrait photo [9]. The average soft tissue thickness expected is determined by age and gender. A further factor determining the average and the actual facial tissue thickness is ethnicity and genetics, respectively [2, 18, 19]. By keeping the possible extreme values for each landmark in mind, the nutritional status of the person in the portrait photo can be taken into account [9].

There is recurrent discussion about the way the averages for facial soft tissue thickness are obtained. The first approach, historic, was to measure a series of skulls and a series of faces of living persons as a means of comparison. The resulting difference in the averages for each landmark site was used as the value for the facial soft tissue thickness of that site [4]. First, direct measurements of facial tissue thickness were taken from the dead: for this purpose, a knife, whose blade had been filed blunt at the tip, was poked into the tissue over the landmark site until it hit the bone; the depth of penetration was then recorded [27]. Artifacts due to the supine position of the subjects occurred in this method, just as they still do in measurements taken from postmortem, and in vivo, CT or MRT scans [12, 18]. While sonography is a suitable method for obtaining facial soft tissue thickness values from seated living persons, artifacts due to the surface pressure can occur. However, in view of the high inter-individual variability of soft tissue thickness values, the influence of such, relatively minor, systematic measurement errors during data collection should not call the use of these values in practice into question. The actual differences in the thickness of soft facial tissues due to gender, age, ethnicity, state of health, and personal life circumstances are greater than measurement errors incurred in the calculation of average tissue thickness [14].

In the following case report, we illustrate how it is possible to achieve an optimal live view alignment of a skull with tissue depth markers to a reference portrait prior to photographing it for the superimposition technique by using Afloat® freeware. The technique does not require a complicated equipment setup.

## Case report

During a police investigation in January, a partially skeletonized corpse was found in a garden hut. There was suspicion that it could be the corpse of a 56-year-old man who had been reported missing 9 months earlier. An antemortem DNA profile from the man and a portrait photograph were available for comparison. Dental records could not be obtained.

Autopsy revealed that the corpse was greatly affected by autolysis, putrefaction, and insect damage. The skin was mummified in parts, and adipocere had developed in some of the soft tissues. The organs had been reduced to small amounts of sticky paste. Hide beetles, maggots, flies, and numerous empty pupal cases could be found on the corpse. There was no indication of bony injuries. Bone characteristics indicated that the individual had most probably been a middle-aged to older male. The teeth, of which many were missing, were strongly abraded, and the partial dentures found on the upper and lower jaw had almost been worn down to the plastic base in places, similar to the wear that is observed after decades of use. The skull and jaw were macerated and stored for further examination.

Several attempts at obtaining a DNA profile from the tissue samples collected during autopsy were fruitless.

## Materials and methods

### Reference photograph

The reference portrait photograph had been taken by a police records department approximately 17 years before the man was reported missing. The photo was taken in left half-profile, with the head slightly inclined to the right and lifted somewhat above the Frankfurt horizontal plane (Fig. 2). The proportions of the face did not reveal any indication of the so-called nearness, or "dog nose" effect [25, 26]. The 9×12.5-cm photo was scanned at a resolution of 600 dpi for further digital processing.

## Preparation of the skull

The skull and lower jaw were cleaned of all remaining soft tissues and then macerated by being placed in an enzyme solution (per 7 l of water: 105 g sodium chloride; in addition, 35 g Papain, 7 g Mollescal C, 7 g Supralan 67, and 7 g Supralan UF (all from Bauer Handels GmbH, Adetswil, Schweiz) were added; the solution was buffered with sodium carbonate to maintain a pH value between 7 and 8.5) for 7 and 5 days, respectively. Loose teeth were glued into their sockets, and the partial dentures on the upper and lower jaw were fixed into place. A self-adhesive spacer was inserted into the temporomandibular joint, and the lower jaw was tied to the skull with packthread. Fifty-three markers, which had been previously fashioned to indicate the average facial soft tissue depth given in the literature, were glued to the skull to mark the tissue depth at each anthropological landmark site [9]. In conclusion, the skull was fixed on a craniophor.

## Afloat® software

Afloat® is free software that can be downloaded from the internet [1]. It only runs on Macintosh operating systems Mac OS X 10.5 or higher. Afloat® permits the depiction of all programs created with the Cocoa application programming interface in varying stages of transparency and also allows overlaying, or floating, a window on top of all others. Among other features, Afloat® can change the depiction mode of Adobe Photoshop CS4 and the OS X Preview program.

## Obtaining an aligned photograph of the skull for the superimposition technique

The skull was positioned at a distance of 2 m in front of a Nikon Model D 300 camera with a 90-mm prime lens. The camera image was displayed in live view mode on the computer screen using the Camera Control Pro (v. 2.7.0) software from Nikon. Then the window with the digitized portrait image, which had been opened with Preview and could be scaled for size, was made semi-transparent and floated over the live view window showing the skull with the Afloat® (v. 2.1) software (Fig. 1). In the live view window, the skull with the tissue markers could then be aligned along the anatomical axes to match the orientation of the portrait in the overlying window. The skull that had been thus aligned to the reference portrait was then photographed to obtain an aligned skull image for the superimposition technique.

## Comparison

First, all conspicuous morphological characteristics apparent on the portrait were noted. These characteristics were then looked for both directly on the skull and on the image of the aligned skull.

The portrait image and the image of the aligned skull were opened in a common Photoshop CS4 file and were projected on top of each other. The portrait photograph was floated over the skull image in different stages of semi-transparency. In this view, the pictures were scaled for size, while keeping the proportions constant. Appropriate scaling of the photographs was determined with the aid of

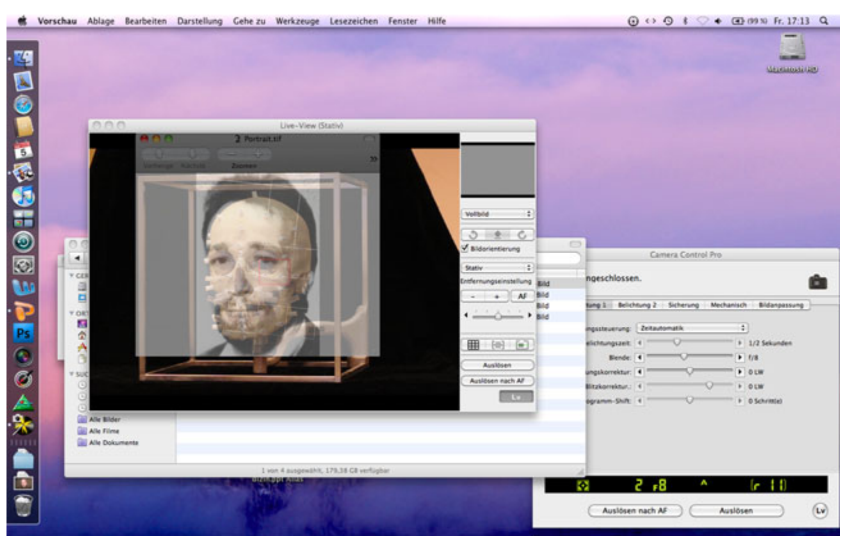


**Fig. 1** Screenshot with Camera Control Pro and Preview software. Semi-transparent depiction through Afloat®

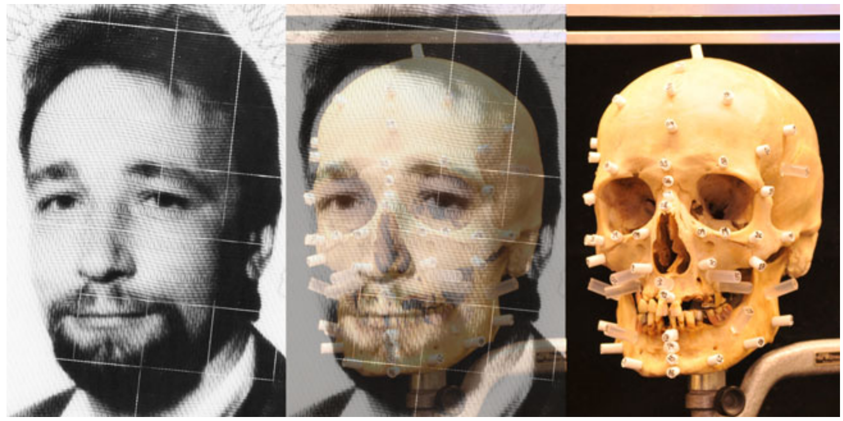

**Fig. 2** *Left* portrait photograph. *Right* photograph of the aligned skull. *Middle* superimposition with Photoshop

orientation lines along the root of the nose, the floor of the nose, the bridge of the nose, and the assumed position of the mouth.

## Results

When the portrait image and the image of the aligned skull (Fig. 2) were compared at the right scale, conspicuous morphological matches were found: a high, slightly rounded forehead, the general length and width of the face, a pronounced glabella, the deviation of the bridge of the nose to the left, and a robust lower jaw. Furthermore, the facial proportionality of the portrait and the aligned skull (Fig. 2) was in accordance for horizontal lines drawn through the middle of the eyes, the spina nasalis, and the mouth. During superimposition, the aligned skull image could be completely fitted into the face in the portrait image. The tissue markers on the right side of the forehead and cheek exactly matched the contours of the portrait; they only jutted out a little over the edges of the portrait in the right-hand region of the lower jaw (Fig. 2).

## Discussion

Being able to align a skull in live view with a semi-transparent image of the reference portrait floated over it enormously facilitates obtaining a skull image that can be used for the superimposition identification technique. The first version of this technique was Helmer and Grüner's video-mixing technique [10, 11]. An economical modification of the technique using currently available video and computer technology was presented by Fenton et al. in 2008 [6]. The main disadvantage of this technique is, however, that the resolution is limited by the video format—at least for the image of the skull.

So far, there was no technological solution for the alignment of a skull photograph with the high resolution typical for a digital reflex camera to an overlaid portrait photograph in live view. In the past few years, leading camera manufacturers have increasingly brought digital reflex cameras with a live view function onto the market. Canon even supplies camera control software along with many of its models that allows the display of live images on a computer screen. This function has now been available for several years for many of Canon's compact cameras. For Nikon, the Camera Control Pro software used in this case has to be purchased separately.

To date, the super-projection of a photograph onto the live view image from a camera was impossible. The only option so far was to tile a portrait image next to the live view image on the same computer screen. An exact alignment of the skull, comparable to that achieved by superimposition, was impossible. Now, the Afloat® software, which runs on the Macintosh operating systems Mac OS X 10.5 or higher, and which is a Cocoa extender that can make a window transparent and overlay, or float, over all other windows, offers a technical solution to this problem. What is amazing is that this valuable tool is freeware. In effect, this means that users who are already working with an Apple computer, and have a digital camera, only need to acquire the necessary camera control software—provided this wasn't supplied along with the camera—to complete the equipment setup for the technique we are introducing here. Our technique yields high-quality images of the skull in the same orientation as the reference portrait photograph. By contrast, approaches which digitize the skull in 3D [5] are not only far more elaborate and expensive, they also yield lower quality images of the skull than the technique presented here. Despite the concessions that need to be made to poorer resolution, the 3D reconstruction of a skull from a postmortem CT scan [22, 24] does offer the advantage that the skull does not have to be macerated first. This advantage can be essential when results are needed fast. On the other hand, the 3-D reconstruction method requires a sufficiently high resolution of CT data sets [24] and the availability of a CT scanner for the postmortem CT scan—a prerequisite that perhaps not every facility can fulfill.

## Conclusion

In combination with a live view-capable digital reflex camera, camera control software, and a Macintosh computer, the Afloat® freeware allows the alignment of a skull to a superimposed reference portrait image prior to photographing. With this simple and inexpensive method, high-quality images of an unidentified skull can be obtained in the orientation required for superimposition with a reference portrait.

## Dedication

This paper is dedicated to Prof. Dr. med. Richard Helmer, a pioneer of modern skull identification and founder of the International Association of Craniofacial Identification, who died on January 23, 2010.

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