# Analysis of Supraorbital Margins in human skull for characterization of sexual dimorphism

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***Abstract*—Sex determination in human skeletal remains is one of the most important steps in forensic pathology and skeletal anthropology. In addition to the pelvis, the skull is the most commonly used skeletal site to determine males and females, and the supraorbital region which includes the supraorbital margin is considered a crucial sexually dimorphic trait. Unlike the visual or morphoscopic approach, where sex is determined through the visual and tactile assessment, the present study aims to propose a methodology based on an objective quantification of the sexually dimorphic features. Using Wavelet Transform as a multi-scale tool allows measuring shape variations which are hidden at different scales of resolution. Our analysis has shown good results which may contribute to sex determination and allow experts to construct biological profiles of human skeleton as well as to monitor the geographical and temporal variations within and among populations.**

***Keywords*-Multi-scale analysis; Sex determination;**

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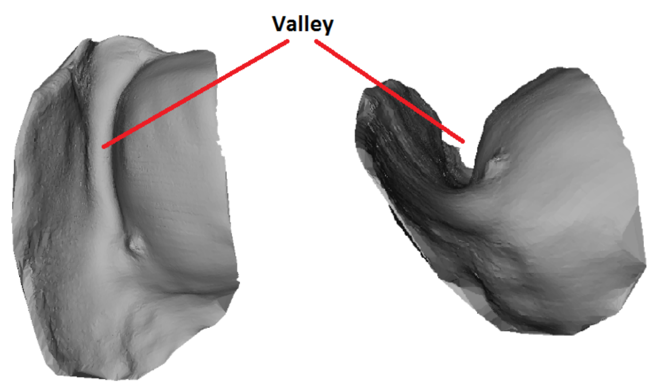


Fig. 1. Visualization of a supraorbital margin by top and lateral views.

## I. Introduction

Sex determination of unknown skeletal remains is a fundamental procedure in executing an anthropological examination. In the context of forensic investigation, sex diagnosis, together with assessment of age, population affinity and stature, is considered a major requirement in the process of personal identification. The concept of sex determination using skeletal remains is based on sexual dimorphism, which is generally present in most bones of the human skeleton, although in varying degrees. There are two main anatomical sites of the skeleton, which are widely used for sexual diagnosis: pelvis and skull.

Traditionally, anthropological methods for the sex diagnosis of human skulls are divided into two categories, morphoscopic and morphometric. The former assesses a set of cranial traits by comparing, visually and via palpation, with sex-related standards (schemes and/or physical models) [1], [2]. The latter aims to quantify the size and shape variations using the same set of traits [3], [4], [5].

*Contributions:* Different from diagnosis by traditional morphometric based on global measures such as volume and surface area [3], [6], the present study focuses on showing the sex diagnosis by analyzing the skull surfaces limited to the region of morphological importance, i.e. through of local measures takes into account differential features of surface. For this reason wavelet has been efficiently used in biomedical shape analysis [7], [8], due to its propriety in analyzing singularities and extracting differential information from the signal.

### A. Related work

In contrast to the cranial morphology as a whole, anthropologists' attention has been given only trying to quantify the change in morphology of the supraorbital margin. In previous study [1], [2], [9], [10], anthropologists have found sexual differences with regard to form of the valley of the supraorbital margin (see Fig. 1). It had been generally noticed that female supraorbital margin is present by the valley form and is very sharp at its edge, ”like the edge of a slightly dulled knife”, while male margin has the valley form more rounded, i.e., ”with a curvature approximating a pencil” [11].

### B. Technique overview

We have implemented a wavelet-based method to extract multi-scale differential features of valley region of supraorbital margin. Thereafter, we suggest an approach based on thresholds to segment the region of interest, and so, to make measurements which can contribute, through a simple graph, by arrangement of two distinct regions characterizing a prior classification of the supraorbital margin according to sex.

## II. Technical background

The 3D scanner provided a point cloud from supraorbital margin. In order to align these points in a manner suitable to our algorithms, we applied a pre-processing step which transformed the point cloud into a surface of the type $z = f(x, y)$ allowing to apply the 2D wavelet. We had to be careful while dealing with problems like filling holes and minimize the border effects caused by wavelet. Additional technical notes can be found in [7].

Let $\mathbf{x}(x, y) \in \mathbb{R}^2$ be the vectorial notation of 2D point. The continuous wavelet transform (CWT) of a 2D signal $f(\mathbf{x})$ is defined as [12]:

$$W_\psi(b, a) = \frac{1}{\sqrt{a}} \int \psi^*(\frac{x-b}{a}) f(x) dx \quad (1)$$

where $\psi^*$, $b$ and $a$ represents the complex conjugate of the analyzed wavelet (or "mother wavelet"), the shifting parameter and the dilation parameter (related to analyzed scale), respectively. Different mother wavelets can be used, depending on the type of information expected to be extracted from the signal. The derivatives of the Gaussian are particularly suitable for analyzing singularities and extracting differential information from the signal, so we have worked with the first partial derivatives with respect to $x$ and $y$ of the 2D Gaussian function $\phi(x, y)$ denoted as $\psi_x$ and $\psi_y$:

$$\psi_x(x, y) = \frac{\partial \phi(x, y)}{\partial x} \quad \text{e} \quad \psi_y(x, y) = \frac{\partial \phi(x, y)}{\partial y} \quad (2)$$

where the 2D Gaussian function is:

$$\phi(x, y) = e^{-\frac{(x^2+y^2)}{2}} = e^{-\frac{|\mathbf{x}|^2}{2}} \quad (3)$$

In order to study morphological variation of supraorbital margin, we have assessed the potential of the wavelet for numerical multi-scale estimation of the gradient field of morphological shapes. Therefore, we have applied the 2D wavelet transform ($W_{\psi_x}$ and $W_{\psi_y}$) in the expanded surface for the purpose of calculate the gradient $\nabla_W$, i.e.,

$$\nabla_W = \left(W_{\psi_x}, W_{\psi_y}\right) = \left(\frac{\partial f(x, y)}{\partial x}, \frac{\partial f(x, y)}{\partial y}\right). \quad (4)$$

The gradient-based measures has the advantage of being invariant to translation and rotation, which is a significant property which guarantees that anatomical correspondences of supraorbital margin is independent of its orientation relative to scanner. From the gradient field (see Fig. 2), we can measure its entropy, which quantifies the degree of disorder of the vector orientation of the analyzed surface.

Considering a small neighbourhood of voxels for each point $(x, y)$ of the surface, the entropy is locally calculated and its value is assigned to a texture value of supraorbital margin surface, as we can check the image of Fig. 3. The features, which must help to describe the degree of sexual dimorphism in supraorbital margin, are extracted from the entropy-based texture.

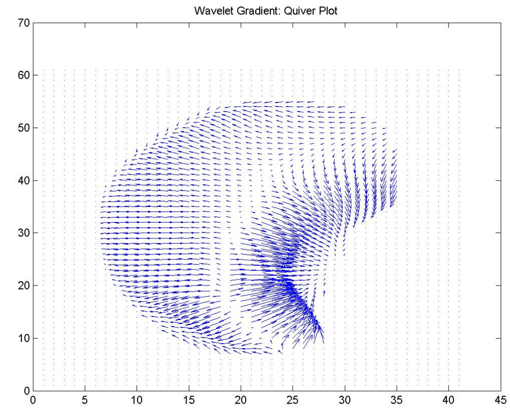


Fig. 2. Gradient field as the top view of the surface of a supraorbital margin.

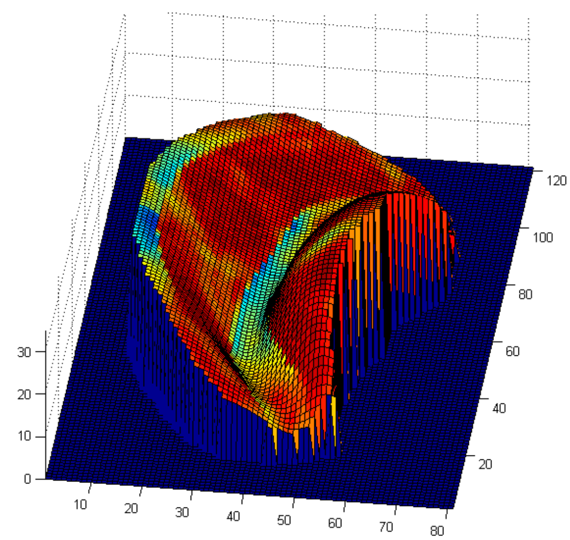


Fig. 3. Entropy of the gradient field allocated for the texture value of a supraorbital margin surface.

From two thresholds, one for the height value $t_h$ surface and one for the entropy $t_e$, we apply the segmentation procedure for acquiring the region of interest, i.e., the valley region of supraorbital margins (as discussed before), as shown in Fig. 4. Two measures are made by region of interest: the area and the thickness, which is defined as the number of erosions are necessary to completely erode the area [12].

## III. Experiments

For this investigation, we used some supraorbital margins samples provided by the Department of Anthropology at the Masaryk University, Czech Republic. The data set consisted of 21 supraorbital margins samples, nine (9) female and twelve (12) male, being divided into left and right side of the skull, according to Table I.

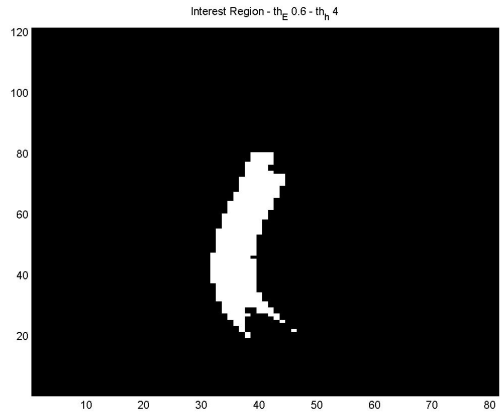


Fig. 4. Region of interest after segmentation though by $t_h$ and $t_e$ thresholds.

TABLE I
DATA SET: EACH NUMBER IS THE IDENTIFICATION (ID) OF INDIVIDUAL.

| Female | | Male | |
|---|---|---|---|
| Left | Right | Left | Right |
| 276 | 42 | 245 | 53 |
| 361 | 264 | 299 | 69 |
| 475 | 333 | 324 | 92 |
| | 343 | 407 | 97 |
| | 361 | | 201 |
| | 475 | | 224 |
| | | | 265 |
| | | | 424 |

## IV. RESULTS AND DISCUSSION

The present results are based on the measures of the region of interest, i.e., valley region. We have worked with four different values for the threshold $t_h$ and three different values for the threshold $t_e$. These values have been choice by observations in the entropy surface. These 12 features were obtained for each five different scale of 2D wavelet.

Figures 5 and 6 present the two-dimensional feature space defined by the area and thickness of valley region with respect to two classes of individuals: male and female. Out of 60 possible combinations, these two plots were those with better discriminating abilities for male and female classes. Importantly, in this feature space there is not concern in separating supraorbital margins from different sides of the skull, i.e., right and left, but can present two different regions of clustering of samples in relation to sex.

## V. CONCLUSION

In the present paper, we have introduced a new method to characterize the degree and pattern of sexual dimorphism in supraorbital margins. The results obtained until now can be considered satisfactory, since, one of the concerns of this study was to develop a methodology, which could possibly be recorded, in a systematic way, the characteristics not adequately captured and/or observed in pattern analyses of skull morphology. However, due to the fact of being a work in progress, some methodologies have been studied for achieving better results as, for example, testing new parameter for scales and thresholds, doing new measures for valley region, and others.

We believe that the present method may be helpful in constructing biological profiles for unknown human remains and be useful for monitoring geographical variations and temporal changes in cranial features. Once this method proves its capability, it can easily be extend to other regions of skeleton, such as other sexually dimorphic traits of the cranium or regions of morphological difference related to disease or population affinity.

The authors are writing a full paper with more details about the implementation of features extraction and the newer results.

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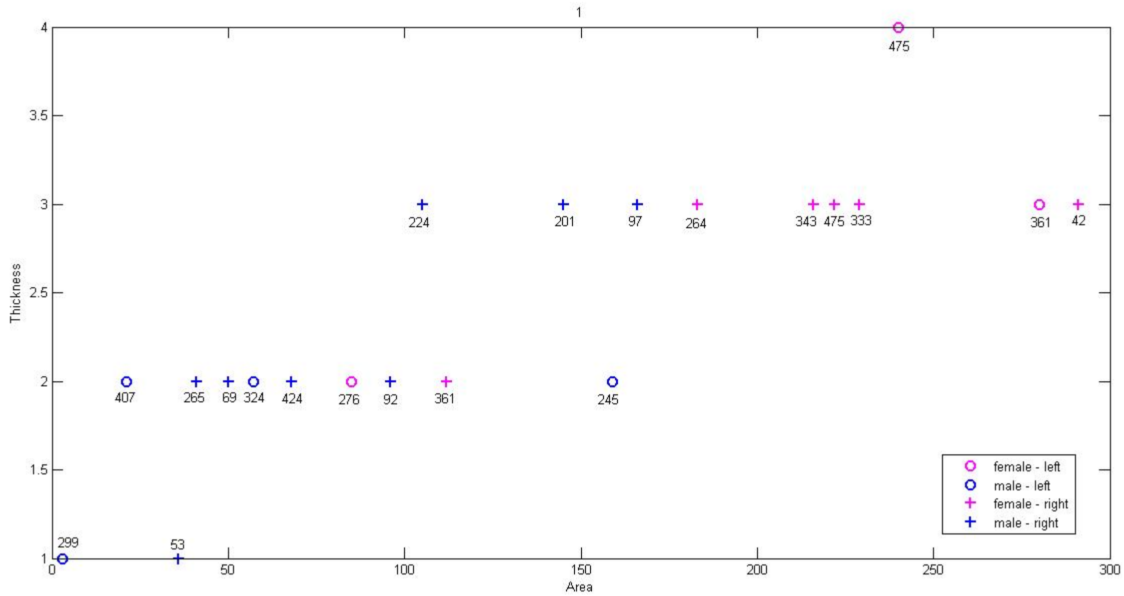


Fig. 5. Two-dimensional feature space of Area and Thickness of valley region considering scale $a = 0.00005$, $t_h = 2$ and $t_e = 2$.

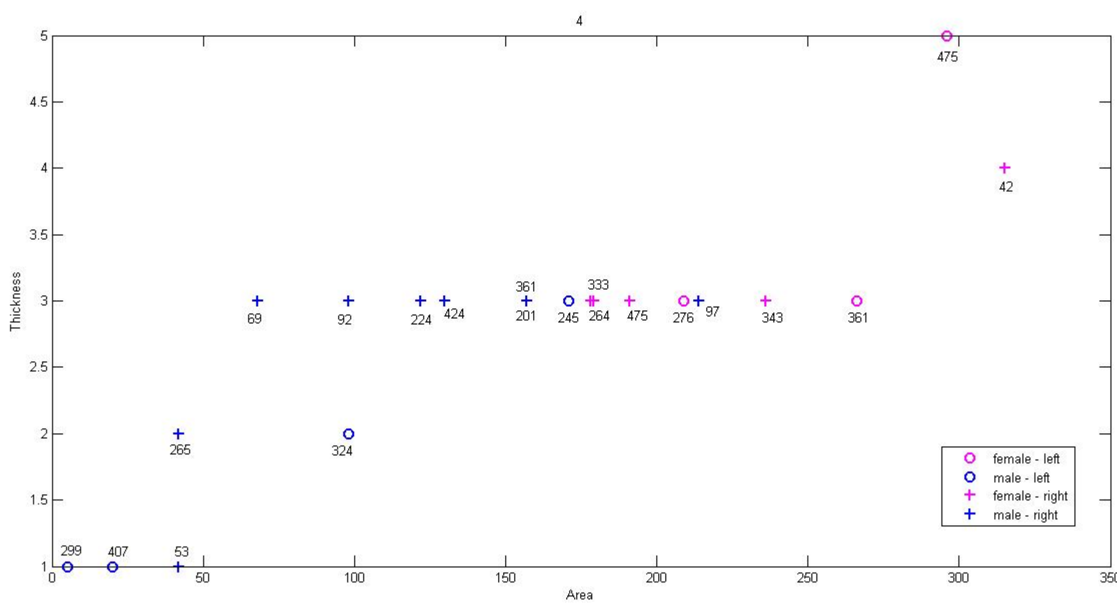


Fig. 6. Two-dimensional feature space of Area and Thickness of valley region considering scale $a = 0.000025$, $t_h = 3$ and $t_e = 2$.