Age estimation from 3D X-ray CT images of human fourth ribs

JC. Prieto[1], S. Mihaila[1], A. Hilaire[1], L. Fanton[1,2], C. Odet[1], and C. Revol-Muller[1]
[1] CREATIS, CNRS UMR 5220, Inserm U1044, Université de Lyon 1, INSA-Lyon,
7 av. Jean Capelle, Villeurbanne F-69621 , France.
[2] Université Lyon, Institut Universitaire de Médecine Légale, Lyon F-69008, France.

Abstract— *This project consists in the evaluation of the feasibility to estimate the age of death from the analysis of 3D X-ray images depicting human fourth ribs. An image processing chain is described, aiming at automatically analyzing the sternal end of the fourth rib, which is known to be reliable to evaluate the person age, since distinctive modifications occur at this extremity during a human life. This first study relies on a set of 14 ribs acquired by X-ray CT imaging. In the final work, the analysis and the validation of our method will be led on more than 400 samples of human ribs.*

Keywords: 3D X-ray Imaging, Medical Imaging Processing, Morphological Operation, Forensics

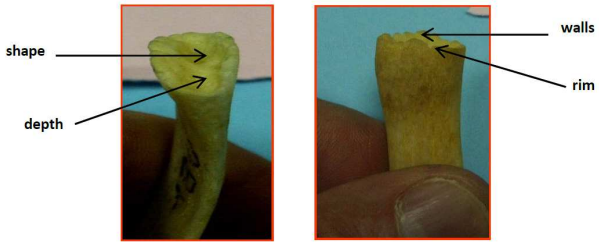


Fig. 1: Iscan method parameters.

1. Introduction

In Forensics, age estimation is an important element of human identification process. In case of serious trauma, this parameter is crucial to identify the victims. Many forensics techniques are based on the study of skeleton parts to determine a person age [1]. Among these methods, four of them focus on the analysis of the femur cortical bone, the pubic symphysis, teeth and sternal ribs [2], [3], [4], [5], [6], [7]. For our work, we focused on the Iscan method, which allows to evaluate a person age, according to the analysis of the sternal end of his fourth rib. This macroscopic technique relies on the observation of distinctive modifications for the sternal end, during a human life. Indeed, for adolescents, this region is billowy and flat (phase of immaturity < 35 years old), then two small pits appear (phase of maturity ≈ 35 years old) and reach in order to form an irregular shape with excrescences (aging phase). For males, these excrescences are usually on the borders of the ribs and for females, they can also appear inside the pit of the sternal end. To implement the Iscan method, it is necessary to study the aspect of the sternal end, in terms of depth, shape, walls and rim of the pit (see Fig. 1). The Iscan technique supplies objective information on the age of death. Nevertheless, a recent critical study of this method indicates that it has a low reproducibility and repeatability, and need to be improved. The process also depends on the gender and the ethnical origin. In order to optimize the technique, researchers have demonstrated that the parameters can be calculated by a human operator, with 2D or 3D X-ray images. Moreover, it has been proven that the shape of the sternum end can be described by 2D Fourier transform. Therefore, we wanted to go further by using 3D image processing functions to replace the Iscan method.

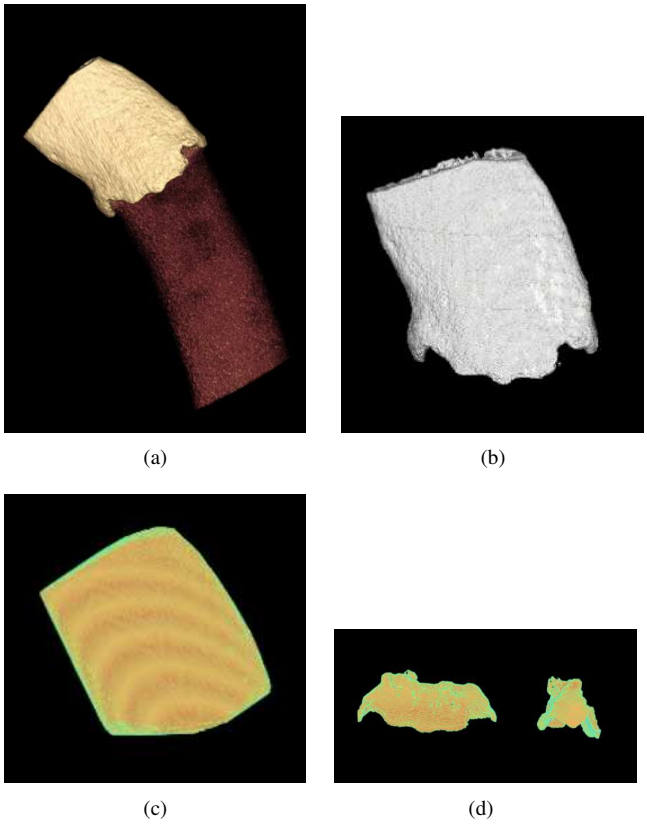
2. Method

2.1 Material

For our study, we had fourteen 3D X-ray images of sternal ribs obtained with the same technical process (calibration and acquisition) with a voxel size of 0.11124mm x 0.11124mm x 0.11124mm. The image database contained samples from males and females of several age groups. The long term goal of our project is to allow forensic scientists to automatically evaluate the age of death with a simple 3D image capturing and processing system, and no bone extraction. In case of success, this automatic method could be transposed to the analysis of the pubic symphysis, in order to obtain a more reliable age estimation based on two complementary methods.

2.2 Principle

The purpose of the paper is to study the cavity of the 4th sternal rib and to run statistics in order to find some clusters depending on the age of the person. This work is in progress, thus at this step, we managed to isolate the internal surface of bone cavity of the rib, extract the 3D crest of this cavity and make 2D parallel projections from the reoriented cavity. We ran our studies over 14 bones which are not sufficient to have meaningful conclusions but allow to test the feasability of our approach. However the preliminary tests showed that there is a correlation between them. Our processing chain can be resumed as follows: 1) apply a segmentation to extract the bone from the cartilage; 2) calculate the convex hull of the binary object; 3) create a mask in order to extract the



(a) (b) (c) (d)

Fig. 2: Fourth rib processing: a) initial 3D X-Ray image of the fourth rib; b) bone extraction; c) convex hull of the bone; d) extraction of the bone cavity.

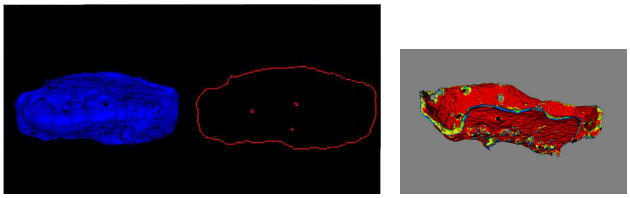
internal surface of the bone cavity of the rib; 4) extract shape features of the cavity.

1. The 3D X-ray images contained information encoded in 2 signed bytes. The original image is transformed into a binary image by using a threshold filter (all grey levels lower than 500 Hounsfield Units received the value 0 and the others the value 1). These images are then used for further treatments.

2. The surface of the object is extracted from previous the binary image. From this surface, the convex hull is computed. The convex hull will locate roughly the sought bone cavity of the rib. This larger region of interest ensures to contain the cavity, thus facilitating its extraction. The convex hull is transformed back into a binary image where the interior of the surface will be labeled 1 and the exterior 0.

3. Afterwards a differentiation operation between the convex hull image and the original image is applied. Both ends of the cavity are very close to the convex hull's borders, so an erosion filter can easily detach the object into two parts. We are interested in keeping the internal part which contains the bony growths. Once the separation is done, a region growing segmentation is performed. The mask is finalized by a dilation operation. A binary multiplication between the mask and the original data allows to get the bone cavity of the rib.

4. To extract the 3D crest of the cavity, the maximal principal curvatures at each point of the surface are computed and only the points maximizing the curvature are kept. Further analysis based on SPHARMs will be done. Since the ellipsoidal shape of the cavity is a meaningful feature, we also project the cavity after reorienting the images in order to calculate 2D Fourier descriptors.



(a) (b)

Fig. 3: Process for features extraction: a) parallel projection of the cavity; b) maximal principal curvature of the cavity surface.

3. Perspectives and Conclusion

We proposed an image processing chain to automatically analyze the sternal end of the human fourth ribs. In the final work, a statistical study will be led on a large set of 400 CT images of human ribs. Starting from shape descriptors such as 2D Fourier descriptors and SPHARM coefficients, PCA will be computed in order to reveal patterns and observe clusters depending on age. We should then achieve a more robust estimation of the age than the classical Iscan technique.

References

[1] Laurent Fanton, *Estimation de l'âge au décès à partir de la 4ème côte*, Ph.D. thesis, Laboratoire d'Anthropologie Moléculaire et d'Imagerie de Synthèse,UMR 5288, 2009.

[2] MY Iscan, SR Loth, and RK Wright, "Age estimation from the rib by phase analysis: white males.," *J Forensic Sci*, vol. 29, no. 4, pp. 1094–104, Oct. 1984.

[3] E Baccino, DH Ubelaker, LA Hayek, and A Zerilli, "Evaluation of seven methods of estimating age at death from mature human skeletal remains.," *J Forensic Sci*, vol. 44, no. 5, pp. 931–6, 1999.

[4] B Foti, P Adalian, M Signoli, Y Ardagna, O Dutour, and G Leonetti, "Limits of the lamendin method in age determination.," *Forensic Sci Int*, vol. 122, no. 2-3, pp. 101–6, Nov. 2001.

[5] N Telmon, A Gaston, P Chemla, A Blanc, F Joffre, and D Rouge, "Application of the Suchey-Brooks method to three-dimensional imaging of the pubic symphysis.," *J Forensic Sci*, vol. 50, no. 3, pp. 507–12, May 2005.

[6] MS Megyesi, DH Ubelaker, and NJ Sauer, "Test of the lamendin aging method on two historic skeletal samples.," *Am J Phys Anthropol*, vol. 131, no. 3, pp. 363–7, Nov. 2006.

[7] F Dedouit, S Bindel, D Gainza, A Blanc, F Joffre, D Rouge, and N Telmon, "Application of the iscan method to two- and three-dimensional imaging of the sternal end of the right fourth rib.," *J Forensic Sci*, vol. 53, no. 2, pp. 288–95, Mar. 2008.