Modelling Mandible Articulation for Skull-Face Overlay in Forensic Identification[1]

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I. Introduction

Forensic anthropology is a sub-field of physical anthropology that involves applying scientific knowledge to the collection and analysis of medico-legal information. It includes the recovery, identification, and description of human skeletal remains [2]. Currently, several forensic identification techniques are available, i.e., DNA samples, fingerprint recognition, or dental records. When none of the previous methods can be applied, the analysis of skeletal remains becomes the last resort of forensic identification. One of the alternative techniques is craniofacial superimposition (CFS) [3], which involves the superimposition of a complete skull (or a skull model) with a number of *ante mortem* (AM) images of an individual. CFS is thus a technique used when only skeletal information is available for the forensic assessment and other techniques such as DNA or dental record analysis are not possible or conclusive.

Traditional CFS techniques are tedious and based on a 'trial and error' process requiring several hours of manual processing to obtain a correct superimposition. Therefore, there is a strong interest on designing automatic methods to assist the CFS identification procedure [4]. The process requires a forensic expert to position the skull in the same pose as the face in the photograph. This process is known as Skull-Face Overlay (SFO).

Up to now, all computer-based SFO methods have considered the mandible as a rigid part of the skull. These methods usually follow one of the following approaches to approximate the mandible aperture [5]: i) Before capturing the 3D model, the mandible was manually located relative to the cranium so that the model resembled the facial expression of the photograph under study; and ii) Once the mandible and the cranium were scanned, the 3D models were positioned according to the relative aperture in the photograph using 3D modeling software.

Such a simplification (*anatomically incorrect*) causes a negative impact on the accuracy of the automatic SFO method. As the AM images used to perform CFS are typically provided by relatives, the missing person usually appears in relaxed situations, most of them smiling or with the mouth slightly open. Generally, cases with grimaces or forced poses are discarded due to the fact that the mandible is in an exaggerated position and these kinds of facial expressions distort the soft tissue of the face. Additionally, each individual comparison should involve the analysis of one skull against more than one AM photograph of the same person to significantly increase the reliability and accuracy of the method [6]. Overall, this is a very time-consuming task even using an automatic SFO method.

II. Motivation, Proposal, and Conclusions

Those photographs where subjects appear with their mouths open reduce the confidence of the identification. Therefore, it is essential to model the articulation of the mandible in order to improve CFS reliability, considering that we only have skeletal information available to infer its movement. In our contribution, we have modeled and integrated the mandible articulation within the SFO optimization algorithm.

In particular, we considered a simple model [7] to estimate and parameterize the mandible aperture movement using the aperture percentage. Moreover, we proposed different design alternatives to integrate the estimation of the mandible aperture within the scheme of the current state-of-the-art SFO optimization algorithm [8], namely RCGA. Specifically, RCGA is a real-coded, elitist genetic algorithm that performs the registration of the 3D skull with the 2D AM photograph.

Our proposal involves three different design alternatives to balance the exploration-exploitation trade-off during the optimization. We have performed a thorough experimental study to analyze the suitability of the proposed articulation model to the SFO technique. Additionally, we have designed a ground-truth database to allow an objective evaluation of the reliability of our proposal.

According to the results of this experimentation (Figure 1), the application of a simple mandible aperture model has proven its effectiveness, significantly improving the accuracy and the versatility of the state-of-the-art automatic SFO method. Such an outstanding performance facilitates the use of facial photos where the individual either smiles or opens the mouth partially. Such photos have been usually discarded

[1] This article is a summary of the work published in Information Sciences [1], to be considered as a part of the CAEPIA'18 Key Works. The motivation, the main contributions and some conclusions are briefly summarized.

in real identification scenarios. The availability of new AM evidence is a crucial consequence of this work. Indeed, the use of multiple facial photos of the same individual is essential to increase the reliability of the identification based in CFS [9]

In our proposal, the expert is only required to pinpoint the incisors, and the mandibular and cranial condyles, a much simpler task to carry out. This task is only performed once, no matter which number of AM photos the skull is compared with. Thereby, our articulated SFO approach avoids entirely the time-consuming and error-prone positioning of the mandible, besides adding versatility to the procedure as it can adapt its pose to different mouth openings in the photographs.

Acknowledgment

This publication is supported by Spanish Ministerio de Economía y Competitividad under the NEWSOCO project (ref. TIN2015-67661-P) and the Andalusian Dept. of Innovación, Ciencia y Empresa under project TIC2011-7745, both including European Regional Development Funds (ERDF). Dr. C. Campomanes Álvarez's work has been supported by Spanish MECD FPU grant AP-2012-4285. Dr. Ibáñez's work has been supported by Spanish MINECO Juan de la Cierva Fellowship JCI-2012-15359.

References

[1] E. Bermejo, C. Campomanes-Álvarez, A. Valsecchi, O. Ibáñez, S. Damas, and O. Cordón, "Genetic algorithms for skull-face overlay including mandible articulation," *Information Sciences*, vol. 420, pp. 200 – 217, 2017.

[2] M. Yoshino and S. Seta, "Skull-photo superimposition," *Encyclopedia of Forensic Sciences*, vol. 2, pp. 807–815, 2000.

[3] M. Yoshino, *Craniofacial superimposition*, in: C. Wilkinson and C. Rynn, Eds. Craniofacial Identification, University Press, Cambridge, 2012.

[4] S. Damas, O. Cordón, O. Ibáñez, J. Santamaría, I. Alemán, M. Botella, and F. Navarro, "Forensic identification by computer-aided craniofacial superimposition," *ACM Computing Surveys*, vol. 43, no. 4, pp. 1–27, 2011.

[5] M. I. Huete, O. Ibáñez, C. Wilkinson, and T. Kahana, "Past, present, and future of craniofacial superimposition: Literature and international surveys," *Legal Medicine*, vol. 17, no. 4, pp. 267–278, 2015.

[6] S. Damas, C. Wilkinson, T. Kahana, E. Veselovskaya, A. Abramov, R. Jankauskas, P. T. Jayaprakash, E. Ruiz, F. Navarro, M. I. Huete, E. Cunha, F. Cavalli, J. Clement, P. Lestón, F. Molinero, T. Briers, F. Viegas, K. Imaizumi, D. Humpire, and O. Ibáñez, *Study on the performance of different craniofacial superimposition approaches (II): Best practices proposal*. Forensic Science International, 2015, vol. 257.

[7] J. J. Lemoine, J. J. Xia, C. R. Andersen, J. Gateno, W. Buford, and M. A. K. Liebschner, "Geometry-Based Algorithm for the Prediction of Nonpathologic Mandibular Movement," *Journal of Oral and Maxillofacial Surgery*, vol. 65, no. 12, pp. 2411–2417, 2007.

[8] B. R. Campomanes-Alvarez, O. Ibanez, C. Campomanes-Alvarez, S. Damas, and O. Cordón, "Modeling Facial Soft Tissue Thickness for Automatic Skull-Face Overlay," *IEEE Transactions on Information Forensics and Security*, vol. 10, no. 10, pp. 2057–2070, oct 2015.

[9] D. Austin-Smith and W. R. Maples, "The reliability of skull/photograph superimposition in individual identification," *Journal of Forensic Sciences*, vol. 39, no. 2, pp. 446–55, mar 1994.

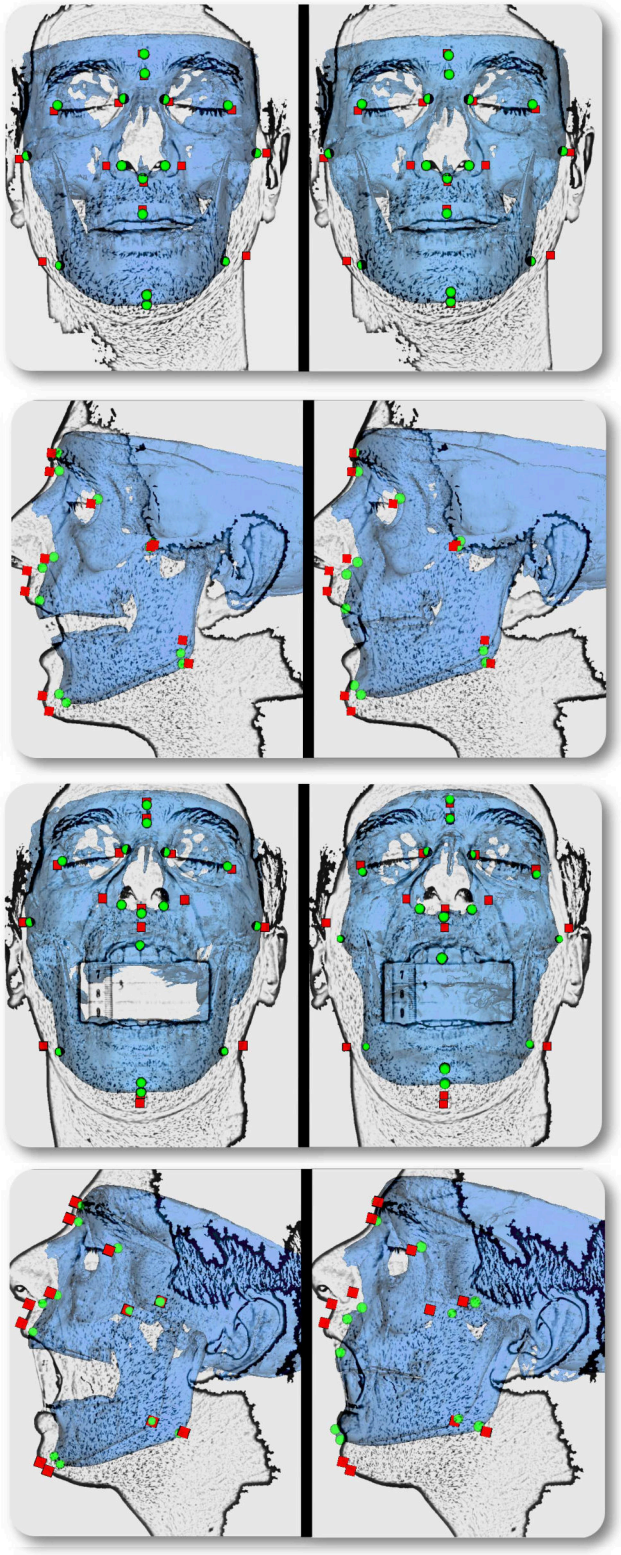

Fig. 1. Visual SFO results: A1 (left images) and RCGA (right images) for different frontal and lateral instances (Smile, 15, 30, and 40).