Validation of a Computational Framework for CT-based Cranio-facial Reconstruction

D. VANDERMEULEN[1], P. CLAES[1], B. DE DOBBELAER[1], G. WILLEMS[2], S. DE GREEF, W. DE VELTER[3], W. VAN DE VOORDE[3], F. TILOTTA[4], Y. ROZENHOLC[5], Á. KUSTÁR[6], P. SUETENS[1]

[1] *Medical Image Computing, ESAT/PSI, Department of Electrical Engineering, KU Leuven & iMinds-KU Leuven Future Health Department*
[2] *Forensic Dentistry, Kapucijnenvoer 7 blok a, bus 7001, B-3000 Leuven, Belgium*
[3] *Forensic Biomedical Sciences, Kapucijnenvoer 33 blok i, bus 7001, B-3000 Leuven, Belgium*
[4] *University Paris Descartes, Faculté de chirurgie dentaire, 1 rue Maurice Arnoux 92120 Montrouge, France*
[5] *University Paris Descartes, MAP5, CNRS UMR 8145, 45 rue des Saints Peres, 75270 Paris Cedex, France*
[6] *Hungarian Natural History Museum, Department of Anthropology; 2-6. Ludovika tér, 1083 Budapest, Hungary*

Email address presenting author: dirk.vandermeulen@esat.kuleuven.be

Estimating the facial outlook from an unidentified skull is a challenging task in forensic investigations. This paper presents the testing and validation of a fully automatic pipeline for computerized craniofacial reconstruction (CFR).

A database of age-, gender- and BMI-annotated full-head 3D cross-sectional Computed Tomography reference scan images is used. This database is continuously being upgraded with new reference cases. Furthermore, the procedure can be easily extended to include data of different ethnicities when such data become available. Facial and skeletal surfaces are automatically extracted and corrected for imaging artifacts or minor anatomical defects (e.g. missing teeth) for every image in the database. Reconstruction of the face of an unidentified skull (scanned 'as is', not requiring a time-consuming soft tissue removal procedure) is started by warping all skull surfaces in the database to the target skull. The resulting transformations are then applied to the associated facial surfaces resulting in as many warped facial surfaces as individuals in the database. A single consensus facial surface is generated by combining the individual reconstructions and taking into account gender, BMI and age matching. By implementing this procedure on a cluster platform, reconstructions can be obtained in less than 10 minutes, irrespective of the number of reference images, which is considerably shorter than current manual reconstruction procedures.

Validation was performed using a cross-validation leave-one-out scenario where each image in the database was reconstructed using all other images in the database as reference. The reconstructed and actual facial surfaces are then compared using statistics of inter-surface distances. We tested the influence of meta-data such as gender, age, BMI and ancestry on the resulting reconstructions using Principal Component Regression.

On a database of 72 reference individuals a maximal reconstruction error of 4 mm was obtained. Errors increased more for BMI mismatches than for age mismatches. Gender mismatches had the smallest influence.