Reconstruction method of 3D objects for facial reconstruction and segmentation of medical imaging

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Facial reconstruction from the knowledge of only the skull is a challenging process with many different medical, legal and even historical applications. Numerical simulation for this reconstruction has been blooming up recently due to the versatility brought by the use of computer framework, nevetheless, in most cases, it is based on a global approach of the face. Segmentation gives rise to recurring problems in medical imaging, especially regarding soft tissues which are, most of the time, difficult to differentiate. We propose here to develop a method to help segmentation in this context.
In this presentation, we shall propose a localized method which 1) characterizes some important muscles of the face (e.g. masseter muscle, temporal muscle), 2) reconstruct them separately only from a skull based on a function-to-shape principle, and for the facial recontruction part 3) add a mask representing the other soft tissues, and 4) then only consider a global process to reconstruct the skin.
The method is based on the one hand on 2-i) the preliminary construction of a large database of accurate segmentations of the desired anatomical item D_k, 2-ii) the extraction by Principal Component Ananlysis, mathematical methods for complexity reduction, of the few most representative items :

$$\sum \langle d_i^k d_i^l \rangle = a_{kl} \quad ; \quad P_l = \sum_{k=1}^{70} v_k^l D_k$$

with A the variance-covariance matrix and a_{kl} its component, k and l number of the item, d_i components of D, v_k^l the k components of the lth eigen vectors of A.
2-iii) allowing, by linear combination, to rebuild all of the others.

$$New = \alpha_1 P_1 + \alpha_2 P_2 + ... + \alpha_n P_n \quad ; \quad \alpha_l = \frac{\sum \langle D_k, P_l \rangle}{\sum \langle P_l, P_l \rangle}$$

And on the other hand 3) the addition of a mask of slightly variable muscles and fat tissues fitted from just a global size aquired from the skull, 4-i) the morphing of the reference skull, with muscles and fat tissues, to the considered skull, with muscles and fat tissues after the steps 2 and 3 above, 4-ii) the application of the same morphing to the reference face to obtain the new face.
We have implemented the first part of our method on the masseter muscle from the manual segmentation of 36 pairs, and discovered that very few representative elements, from 3 to 5 depending on the desired accuracy, suffice to reconstruct each of the 72 masseters. This accurate reconstruction involves 3 to 5 unknown coefficients in the linear combination of the representative elements. Knowledge of these few coefficients is determined from skull measurements or 3D shape of the mandibule, using a machine learning process (neural network). Compared to other more intuitive choices (e.g. height/width/thickness) these coefficients better reflect the masseter shape and allow to recover an almost perfect shape of each masseter, properly associated to the given skull. The other part of this method has been implemented separately on 20 associations skull/face [1].
For the segmentation part, the user will only have to determine the few measurements needed to reconstruct a first guess. And at each additional information for more precision, the whole shape of the muscle will improve.
From this work on a restricted population we believe that it is possible to obtain better results with the preliminary reconstruction of muscles separately that provides a better basis for morphing process (from skull+soft tissues to face), than the plain skull to face reconstruction, and to give an important help for automatic soft tissues segmentation. This method could be used in forensic medicine for victims recognition but also in planning surgery for the face.

Références

[1] M. De Buhan, C. Nardoni, *A mesh deformation based approach for digital facial reconstruction*, submitted, 2016.

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