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Generierung von Referenzmodellen des Schädels durch ein Zwei-Stufen-Verfahren

A two step process for generating normative data of the cranium

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Purpose

As norm data give an idea to the surgeon how the cranium should look like after a surgery, one focal point for the research described in this document at hand was the creation of atlas data of the cranium.

Methods

A method was developed, which is able to construct normative crania by a functional context. This method is combined with a landmark based procedure for improving the results, because of the possibility of the occurrence of ambiguities in the area of the facial bone.
Initial state is a number N of different polygonal models. In the first step, the idea is, to describe the shape of a model by an analytical function, more precisely generating the norm data by a series expansion of spherical harmonics. As these mappings represent a complete functional system, every function defined on the unit sphere can be reconstructed by a weighted series expansion of spherical harmonics.
By transforming the polygonal models, defined in the Euklidian space, on the unit sphere, the shape of the cranium can be characterised clearly by different weighting factors of the base functions. After dividing the data sets in different form classes, arithmetic mean values of the weighting parameters are calculated. The received normative spectrum can be transformed back to a cranial model.
The quality has to be improved in a second step, namely a landmark based procedure.

The surfaces of the different models can be represented by a family of functions, whereas the weighting factors are the parameters and the variables of the function are the two angles characterising a direction in space. By calculating characteristical mathematical points a chosen number of landmarks is identified in this family of functions. The result is a description of the different landmarks depending on the parameters. As the weighting factors for the incoming models are already known, positions of normative landmarks are calculated by an amount of arithmetic mean values. The landmarks are also identified in the norm model generated in the first step, with the modification, that ambiguities are allowed. By the definition of a quality function, which describes the distance of the landmarks from the different data sets to the corresponding mean landmarks and also penalizes ambiguities, an optimization algorithm for the weighting factors of the norm model is executed, which stops if the functional value falls below a chosen threshold or a maximum limit of steps is reached. Landmark based variation in the area of the skullcap can be minimized e.g. by controlling absolute "errors" between the different models.

Results

The entire result is a reference model for each of the form classes. By the reconstruction of one model with spherical harmonics, the accuracy of the first step can be evaluated. A very high accuracy is achieved, which grows up with a decreasing order of the series expansion. In the area of the skullcap already at an order of about 20 the average error decreases under 1%.
At the facial bone the error is slightly decreasing. The creation of atlas data by landmarks is an accepted method, which reaches an high accuracy, if there can be identified enough different landmarks. Here this procedure is only applied to improve the existing data in the area of the facial bone.