STATISTICAL FACIAL RECONSTRUCTION BY TREE FUNCTIONAL REGRESSION ON SURFACES

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Aim: Improvement of statistical facial reconstruction.

Scope: Our work is based on statistical classification of surfaces and estimation of functions defined on them. Instead of using a template, the soft tissue (ST) thickness (STT) estimation is done locally and takes into account local individual skull (SK) specificities by using regression trees. We have acquired a large database of head CT-scans used as a learning database. Statistically, surfaces are compared using recent rigid and non-rigid registration RKHS techniques.

Material: We work on a cranio-facial CT-scans database of 25 living European females, 20-40 years old, with a similar total facial index. Currently, we collected approximately the same quantity of individuals out of this class.
For each individual, the Body Mass Index is estimated. The Dicom data is transferred to software SimPlantPro® 9.22 which restores 3D skull and face.

Methods:

Pre-processings steps:

Extraction of external surfaces of SK and ST and locate sub-surfaces over them.
CT-scan slice segmentation by intensity thresholding. Automatic and manual removal of artefacts (out boundary voxel, metal, …).
Slice by slice, for SK and ST series, computation of an envelop of the region of interest (ROI) using dynamical curves drived by external forces derived from ROI + a curvature control.
Construction of 3D meshes by meshing between successive pair of curves.
Decimation/Regularization of the meshes according to YAMS ensuring quality of individual meshes.
On CT-scans, location of 40 cranio-facial skeleton landmarks according to classical methods of physical anthropology.
We call "patch" a finite ordered landmark sequence.
For each individual and for each patch, we extract the SK mesh surface delimited by the geodesics between successive landmarks of the patch.
On each vertex of a SK mesh, we compute the external normal. Its intersection with the ST mesh defines the STT.

Statistical method:

STT estimation on a dry SK is done according to a CART-like procedure by growing for each patch a regression tree with respect to the CT-scan database.

Given a patch,
associated surfaces are classified according to their geometrical properties using kernel k-means clustering procedure (with automatic choice of k) based on distances derived from rigid and non-rigid deformations associated to some RKHS. This classification defines a set of questions to ask to a dry skull : “Your patch-related SK surface belongs to class(es) X?”.

We call Q the set of all possible questions with respect to any patch and any associated class subset.

Given a patch,
a regression tree for the STT estimation is grown using the set Q. To derive (need) thickness average, we extend the thickness to the whole 3D space using an extension of the previous RKHS construction.

For a new dry SK,
a mesh is built using the method described above.
Given a patch,
the associated tree defines a sequence of questions asked to the dry SK. As a result, the dry SK patch is associated to a sub-family of our CT-scan database. STT estimate is the average of the sub-familly thicknesses.

Results:
Pre-processing and classification steps are implemented. We applied these procedures to the full CT-scan database. From this stage, we obtained (a) an anatomical landmark database, (b) a database of individual meshes for SK and ST, (c) for each selected patch, a database of SK surfaces and associated classification, (d) for each selected patch, a database of STT. We implemented regression trees for STT estimation based on questions derived from previous databases. We obtained promising results on several patches.

Conclusion:
We develop a toolbox for regression on a local surfaces. Its application on a CT-scan database with anatomical extra informations gives promising results for individual STT estimation. Main interests are: individual estimation, local and non local geometry construction, robustness with respect to missing data, natural chirgurical help extension.