MODEL BUILDING FOR INTERACTIVE SEGMENTATION OF THE FEMORAL HEAD

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Background and objectives: Segmentation is the first step when trying to use radiological image data in many clinically important applications as radiological diagnosis, monitoring, radiotherapy and surgical planning. Especially in case of large 3D medical data sets the availability of efficient segmentation methods is a critical issue. Incorporation of prior knowledge about the shapes of the organs can speed up the process and can reduce the amount of the user-interaction. This knowledge can be exploited by statistical evaluation of a training dataset. Before statistical analysis can be started, the individual objects have to be registered in a reasonable way. The spatial distribution of a particular point of a bone can be studied only if that point marks the same part of all bones in the learning database. In other words, a point on a particular anatomical landmark has to correspond to the points on the same anatomical location of the other bones. This correspondence problem is difficult, especially for simple objects, where only a little number of landmark points is available. Solving the correspondence based on solely point-wise anatomical landmarks is often impossible. In these cases, we can still exploit curve- or surface-based shape features of the organs.

The model built up with our method will be the basis of a femur segmentation process, which will allow the user to predict the surface of the femur by the interactive selection of a few, appropriately selected control landmarks.

Design/Methods: A training set of segmented organs was given. We aim at describing these organs by dense triangle meshes in a way that the vertices of these meshes are in anatomically meaningful correspondence. We start from a rough 0^{th} level mesh, which is initialised using the anatomical landmarks defined by the user. Our first study concentrates on the femoral head, containing only two well defined point-wise anatomical landmarks: the fovea and the trochanter minor. An interface has been therefore designed, which enables to use landmarks with higher dimensionality, namely curves and surfaces. The user is requested to mark the crista intertrochanterica and the trochanter major using cubic splines, to approximate the femoral neck at its smallest perimeter with a circle and the femoral head with a half-sphere. After normalization of the orientation of these primitives to the christa intertrochanterica, and their subsequent sparse sampling, the resulting points are projected back to the surface and triangulated in a predefined manner, forming the 0^{th} level in our hierarchical mesh model.

The subsequent levels of the triangle-mesh are generated by systematically subdividing every triangle to four smaller ones. The positions of the new points are determined by pseudo-geodesic interpolation. Instead of real geodesics, we are using projections of the edges of the mesh to the original surface. The direction of the projection is determined by the normals of the mesh triangles. As we are using these curves on relatively flat surfaces (where no anatomical landmarks are available), they are suitable for approximating real geodesics.

Results: The method was evaluated by analysing the statistical model built on the resulted mesh data using point distribution models, proposed by [1]. Our working dataset contained 16 femurs, each with 13889 vertices. The model built on these data proved to be reasonably compact, as the first 8 eigenvectors captured more than 95% of the overall variability. New femurs generated by the model were realistic. Prediction of new shapes was not always exact, but this can be explained with the relatively small number of instances in the training dataset.

Conclusions: The proposed method can be successfully applied in the case when the number of point-wise anatomical landmarks is limited. The statistical model built up with this method is compact and realistic. However, it has to be realised, that the selected landmark structure is highly organ-specific and has to be redefined for every new anatomical region.

References:

1. T. F. Cootes, A. Hill, C. J. Taylor, and J. Haslam. Use of active shape models for locating structures in medical images. Image and Vision Computing, 12(6): 355-365, July/August 1994.