ANATOMIC SEGMENTATION OF STATISTICAL SHAPE MODELS
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Background: Shape segmentation is one of the fundamental tools in shape processing and analysis, and it provides a starting point for building part based shape models. A multitude of methods for segmenting static and dynamic shapes has been developed over the last decades [1] based on various intrinsic and extrinsic geometric features. Interestingly, so far no method seems to make explicit use of a statistical shape model, as the method presented here does. Considering additional model information, a segmentation based on (co-)variation of individual parts can be derived. This allows defining meaningful shape parts in the sense that all points in a part behave similar according to the model, while different parts show distinct variation patterns. This is a desired property for instance in biological morphometrics, where independent modules are sought relating to an underlying independent evolutionary development of corresponding sub-structures. Another application area is motion analysis, where correlation between part movements is relevant for motion understanding and compression.

Aims: To introduce a novel automatic shape segmentation method driven by covariance analysis.

Methods: We use a recent variant [2] of the anatomic covariance tensor [3] to capture covariant behavior between points in a shape model. An inter-point covariance is defined via the model based deformation framework of Blanz et al. [4], i.e. given a perturbation at a specific point the most likely shape according to the PCA model is predicted. It turns out that this relationship can be summarized by a symmetric 2nd order tensor [2]. Based on this tensor we perform a k-medoids clustering of the shape points such that tensors in one cluster are similar to each other. As dissimilarity measure for clustering we use a weighted average of a metric for covariance matrices and the Euclidean distance between corresponding points on the mean shape. Increasing the distance weight allows to enforce spatially connected clusters. In the experiments described here we utilize a covariance metric induced by Frobenius norm, although other well-known metrics like Log-Euclidean could be employed depending on the application.

Results: Segmentations of two different datasets are illustrated together with underlying tensor fields, visualized as in [3]. A volumetric segmentation of a Biological structure is shown in Figs(A-D) using a non-zero Euclidean distance term to yield a strict anatomic segmentation. Figs(E-H) demonstrate the application to a mesh animation, omitting the Euclidean distance term to uncover correlated movements.

Conclusions: The presented clustering based on covariance statistics facilitates automatic anatomic and correlation based shape segmentation, potentially supporting part based shape analysis in future work.

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References:

Figures: (B,E) Illustration of datasets, (A,G) inter-point covariance fields, (D,H) our segmentation results, (C,F) k-means clustering of points for comparison. Note in (D) how clusters a to e nicely correspond to anatomical substructures of teeth, processes and incisor, while clusters i, j, k reflect interior structures.