Local Shape Modelling for Brain Morphometry using Curvature Scale Space

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Methods to capture the morphological variability of the human brain are needed to improve the diagnosis and treatment of neuro-degenerative diseases. This work presents an approach for local shape modelling that models self-similar curves to derive shape information. The method is based on two main techniques: Curvature Scale Space (CSS) as a way to represent contours and obtain a set of meaningful shapes to be analysed, and Statistical Shape Models to characterise the shape variation. The evolution of the curve in the CSS is used to partition the contour into locally similar parts which are then aligned and their variability modelled by PCA. We present the method and demonstrate results on a set of white-matter brain contours.

A set of 40 simulated digital brain phantom images from normal subjects was used in this study. Each digital brain was created after registering and averaging four T1, T2 and PD-weighted MRI scans from normal adults. We have use the white-matter regions from these data sets as the source of our input contours to demonstrate the CSS based local modelling process. Note that a 2D slice-by-slice approach is valid for this particular data as they have been pre-registered.

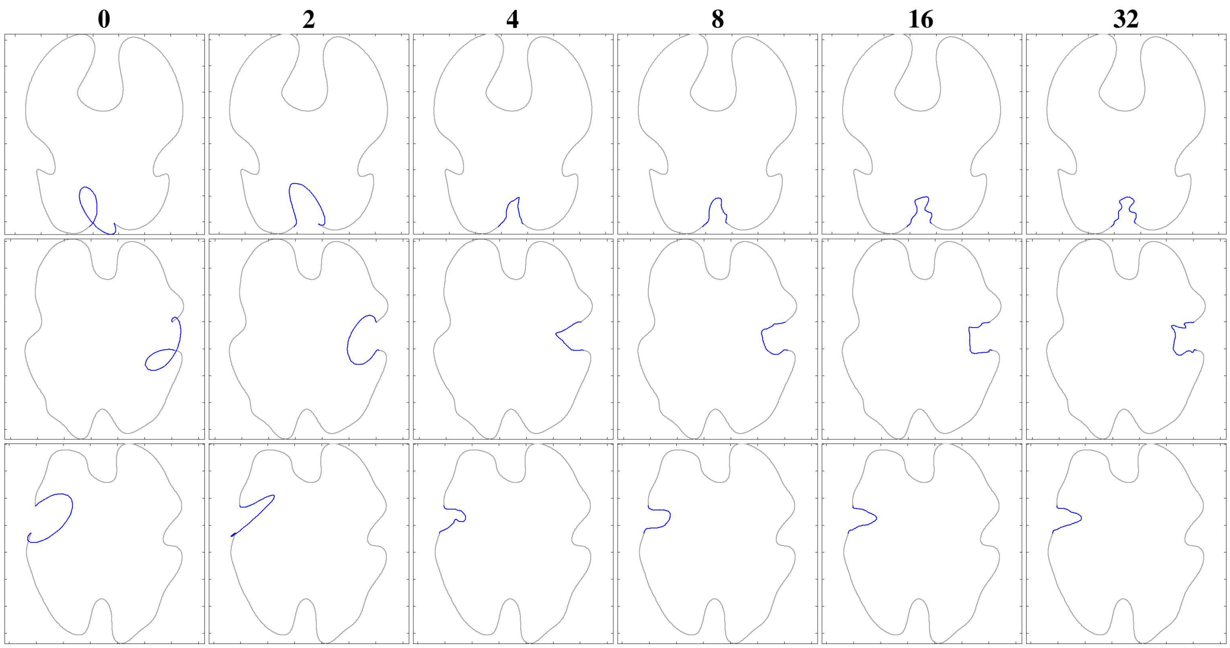

Figure 1. Reconstruction of the chosen set of shapes, by added a sequence of principal modes of variation: 0, 2, 4, 8, 16, 32. The modelled partitions are blended back into a smooth scale of the CSS, Γ^{σ} defocussing the general, irrelevant shape variations for the purposes of visualisation.

The main feature of this work has been the use of the consistency of the curvature extrema at low resolutions of the contour to partition and pose-align locally similar parts of a irregular shape, such as brain contour. This localisation allows a linear shape space to be used directly on the aligned parts. We have introduced a simple windowing and blending technique which allows the modelled parts to be reconstructed back into the original global shape but it is also useful for visual feedback. A limitation of the presented method is the need to resample the partitions to have the same length in order to align and perform PCA. Unless the original contour has many points, any small local part does not have enough to do simple piece-wise-linear resampling. Here, a basis representation would help. The CSS itself is a wavelet representation (by Gaussians), so it could be used directly in a parametric, dimensionless way. An un-supervised version of the this method can be envisaged if the prototype selection and ranking step is replaced by an unsupervised clustering. The clusters could be used to build a set of shape-models, or, alternatively, a non-linear shape learning could be used. The method needs to be extended to surfaces to be properly validated with clinical data but it is not clear a this time how the local partitioning could be easily extended to surface patches.