Non-linear Shape Decomposition using ISOMAP

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Purpose. Linear models are almost always the model of choice for multivariate observations. However, in many situations linear models are likely to fail in accurately modelling natural phenomena. We propose a generalized additive model (GAM) based on ISOMAP coordinates. We illustrate this on various biological shapes (e.g. hands, bones, brain structures).

Methods. Tenenbaum et. al [2] proposed the ISOMAP procedure for non-linear embedding of multivariate data sets into low dimensional parameter spaces. In order to be useful for image segmentation and understanding it is necessary to establish a relationship between the ISOMAP space and the original landmark coordinate space (shape space). We will apply the BRUTO procedure [1] for tting a main effects GAM $y = \sum_i f_i(x_i)$.

Results Compared to standard linear principal components models we achieve a $30 - 50\%$ reduction is the dimensionality of the embedding spaces. In Fig. 1 we show a non-linear mode of variation for the shape of the corpus callosum.

Fig. 1: Shape variation of the corpus callosum along the isomap coordinate axis 1.

Conclusions An ISOMAP based GAM model is a useful alternative to linear models for multivariate models of biological shape.

References

[1] T. Hastie and R. Tibshirani. Generalized additive models. Chapmann and Hall, London, 1990.

[2] J. B. Tenenbaum, V. de Silva, and J. C. Langford. A global geometric framework for nonlinear dimensionality reduction. Science, 290:2319–2323, 2000.