An Evolutionary Strategy for Model–based Segmentation of Medical Data

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Medical image segmentation often involves variants of deformable models to account for both the variability of object shapes and variation in image quality. The model–based segmentation of specific objects is formulated as an optimisation problem that may be solved using gradient descend, dynamic programming, stochastic relaxation and the finite element method, among others. These methods compute a locally optimum solution in terms of a deformable model instance that adapts to the local conditions in the image data, while the set of possible deformations is constrained a-priori.

Segmentation quality, however, highly depends on the initial estimate of the deformable model, and human guidance is often needed to guarantee acceptable results. A deformable shape model can represent the shape and appearance of the anatomical structures of interest, as well as possible variations. Additional information about the object location, size and orientation of the objects within an image is usually introduced by manual initialisation and generation of application–specific statistical shape models, or atlases.

We present a method for automating the deformable model–based segmentation. Our method employs a quality–of–fit function associated with a finite element model of shape in a search for the optimum parametrisation. A global search with an evolutionary strategy is employed to determine the set of optimum pose parameters for initialisation of the shape models. A local search subsequently optimises the non–rigid shape parameters of the model instances by employing the finite element method. The global search controls the segmentation process and returns multiple model–based interpretations of the image along with a confidence measure from the interval $[0, 1]$. Our particular search strategy is inspired by the genetic algorithm of Hill and Taylor (Hill and Taylor, Imag Vis Comp (1992)). It also employs a population of individual solutions that undergo selection on the basis of their associated quality of fit and “mutation” in terms of small, random perturbations of the particular pose parameter values. A major difference to existing shape search strategies (e.g. Cootes, et al., Proc. ECCV’98; Heimann, et al., Proc. IPMI’07) is that the presented quality-of-fit function allows for a reliable evaluation of the model–based segmentations independent from the specific formulation of the parametric prior model. Training may not be required, but statistical information - if available - can be incorporated in a straightforward manner.

Experimental results are presented for different medical applications, which include object detection, localisation and segmentation in MRI and ultrasound data sets, and show the good performance of our approach.