Significance determination for the scale-space primal sketch by comparison of statistics of scale-space blob volumes computed from PET signals vs. residual noise

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Abstract

A dominant approach to brain mapping is to define functional regions in the brain by analyzing brain activation images obtained by PET or fMRI. In [1], it has been shown that the scale-space primal sketch provides a useful tool for such analysis. Some attractive properties of this method are that it only makes few assumptions about the data and the process for extracting activations is fully automatic.

In the present version of the scale-space primal sketch, however, there is no method for determining p -values. The purpose here is to present a new methodology for addressing this question, by introducing a descriptor referred to as the Γ -curve, which serves as a first step towards determining the probability of false positives, i.e. α .

Theory

The scale-space primal sketch is a representation of blob-like structures at different scales, and their hierarchical relations in scale-space. This tool was originally designed for detecting dominant peak-like structures in computer vision images and for determining scale levels for grouping data into regions.

When analysing statistical images obtained by fitting a general linear model to the data, there is a need for another scale parameter, namely the amount of spatial pre-filtering (here, Gaussian smoothing) that is performed before the non-linear statistical descriptors (here, the student-t values) are computed. A secondary goal of this paper is to investigate the influence of this scale parameter.

Method

Given a set of brain activation images obtained from a PET experiment, we first divide the data into subpopulations to increase the amount of data for the statistical evaluation. Then, we fit a general linear model to each subpopulation. This results in one or several contrast (student-t) images as well as a set of residual noise images [2]. From these noise images, reference statistics for the scale-space primal sketch is accumulated at each scale.

In addition, we apply two modifications of the scale-space primal sketch by (i) changing the computation of local contrast to be based on absolute intensity levels instead of relative intensity variations [3], and (ii) removing the rescaling of the amplitude of the reference statistics that was present in the original implementation of the scale-space primal sketch. A companion paper [4] shows that these modifications substantially improve the separation between blobs extracted from PET signal images and blobs extracted from noise images.

For each PET signal image and each noise image in these subpopulations, a scale-space primal sketch is computed. A histogram $f_{PET}(s)$ is accumulated over the scale-space blob volumes S over all PET signal images in the study, and a similar histogram $f_{noise}(s)$ is accumulated over the scale-space blob volumes in all the noise images. From these histograms, integrated histograms $F_{PET}(S)$ and $F_{noise}(S)$ are defined by counting the number of scale-space blobs above any value S . From these integrated histograms, we

form the ratio $\Gamma = F_{noise}(S)/F_{PET}(S)$. This descriptor, which will be referred to as the Γ -curve, describes how many noise blobs there are above a certain threshold relative to the number of blobs in a PET signal image above the same threshold. In this respect, this entity serves as a first estimate of *alpha*.

Results

Figure 1 shows histograms of scale-space blob volumes computed from PET signal images and noise images at scale $t = 0.5$. Figure 2 shows a graph of Γ -curves when using different amount of pre-smoothing to the general linear model. The scale values used here were $t = 0, 0.25, 0.5, 0.75, 1.0, 2.0$ and 4.0 . The varying shapes of these Γ -curves show a clear dependency of the amount of pre-smoothing. A too small amount of smoothing before the general linear model reduces the size of the volume where the general linear model is effectively applied, while a too large amount of pre-smoothing leads to a destructive suppression of fine scale structures. In this experiment, the scale value $t = 0.5$ gives a relatively high signal to noise ratio, while only giving a moderate reduction of the number of blobs in the data.

We conclude that the problem of determining the amount of smoothing prior to the general linear model is of fundamental importance when determining functional regions from brain activation data, and we propose that this problem deserves to be studied in its own right.

References

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