# Evaluation of design options for the scale-space primal sketch analysis of brain activation images

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**Abstract**
**Introduction**
A key issue in brain imaging concerns how to detect the functionally activated regions from PET and fMRI images. In earlier work, it has been shown that the scale-space primal sketch provides a useful tool for such analysis [1]. The method includes presmoothing with different filter widths and automatic estimation of the spatial extent of the activated regions (blobs).

The purpose is to present two modifications of the scale-space primal sketch, as well as a quantitative evaluation which shows that these modifications improve the performance, measured as the separation between blob descriptors extracted from PET images and from noise images. This separation is essential for future work of associating a statistical p-value with the scale-space blob descriptors.

**Theory**
The scale-space primal sketch was originally developed for computer vision applications, dealing with images like photographs of the surrounding world. In such images, structures are primarily considered meaningful with respect to their local contrast. The use of a relative base level, which refers to measuring the amplitude with respect to the immediate surrounding of the blob, was therefore highly motivated. Further, the noise images used for estimating the normalization parameters of the scale-space primal sketch were not necesserily representative regarding their amplitude, e.g. due to illumination effects. Therefore the analysis benefitted from a rescaling of these normalization parameters.

For our application, as a tool for brain activation analysis, the starting conditions are different. In student-t images the absolute voxel values have a meaningful interpretation (i.e. as statistical parameters) and it is essential that only noise images with an appropriate amplitude are used. Therefore, we propose two changes in the original approach: (i) by measuring amplitude with respect to an absolute base level [2] and (ii) by not rescaling the parameters used for the normalization.

**Method**
To increase the number of brain activation images for the statistical evaluation, we created subpopulations from the original set of PET images [3]. By applying the general linear model to each subpopulation, student-t images were estimated for several contrasts. The images were presmoothed prior to the processing (FWHM=3.3mm). The noise images were computed from the residuals from the general linear model [4], thus they were based on the same subpopulations as the PET student-t images. The PET student-t images and the noise images were analyzed by the scale-space primal sketch, using the four possible combinations of absolute vs. relative base level and with vs. without the rescaling. The normalization parameters in the scale-space primal sketch were estimated from the whole set of noise images throughout these experiments, since an evaluation showed that the parameters were consistent over the subpopulations.

For each of the four design options, the scale-space blob volumes, $S$, in all PET images were

accumulated into a histogram, $f_{PET}(S)$. The corresponding histograms $f_{noise}(S)$ were accumulated from all the noise images. From these histograms, integrated histograms $F_{PET}(S)$ and $F_{noise}(S)$ were defined by counting the number of scale-space blobs above any value $S$. From these integrated histograms, we formed the ratio $\Gamma(S) = F_{noise}(S) / F_{PET}(S)$. This descriptor, which will be referred to as the $\Gamma$-curve, describes how many blobs there are in the noise images relative to in the PET images, above any $S$. Thus, a low $\Gamma(S)$ indicates that scale-space blob volumes larger than $S$ have a low probability of appearing by chance.

More details about the procedure for estimating $\Gamma$ and choosing the amount of presmoothing are presented in a companion paper [5].

## Results
Figure 1 shows $\Gamma$-curves for the four combinations of design options described above, i.e. absolute/relative base level and normalization with/without rescaling. A comparison between these graphs shows that the normalization should be performed without rescaling in order to give separation between the PET and the noise images. Moreover, the results show that the separation between the scale-space blob volumes is higher when using absolute base level compared to relative base level. To conclude, we propose that these modifications should be used when applying the scale-space primal sketch to brain activation analysis.

## References
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