Surface- and Volume-based smoothing in fMRI

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Introduction

Smoothing the functional images are usually performed using convolution with the three-dimensional Gaussian smoothing. However this method of smoothing does not take into account the two dimensional structure of the cortical sheet and can therefore result in combining voxels that belong to different cortical areas such as the opposite sides of a deep sulcus, or those belonging to sub-cortical regions as illustrated by figure 1. It has also been shown that Gaussian smoothing can shift the activation centre [1].

(a) (b)

Figure 1 - Gaussian smoothing can spread the original activation (a) to the opposite side of a sulcus

To smooth an image in such a way that smoothing propagates along the cortical sheet, we have developed two surface-based smoothing filters. To compare the performance of our smoothing filters with the volume-based (3D) Gaussian filter, we used retinotopic mapping experiment that is used to find early Visual areas.

Methods

Data acquisition consisted of EPI sequence with voxel size of 3.5 *3.5 * 3 mm for functional data, along with a 3D T1-weighted image with resolution of about 1mm.

We have developed two surface-based smoothing filters for functional images: 1) diffusion smoothing, which uses iterative approach of diffusion smoothing and 2) surface-based smoothing that is based on averaging among the neighbouring voxels along the cortical surface. Both these methods use the information about segmented grey matter and white matter from the T1 image to run the smoothing process on the functional images. To do this, functional images need to be registered to T1 image first.

The polar mapping consisted of a rotating checkerboard wedge. Each complete circular path was divided into 32 lags and the voxels with highest correlation value corresponding to each lag were found. This is described by figure 2.

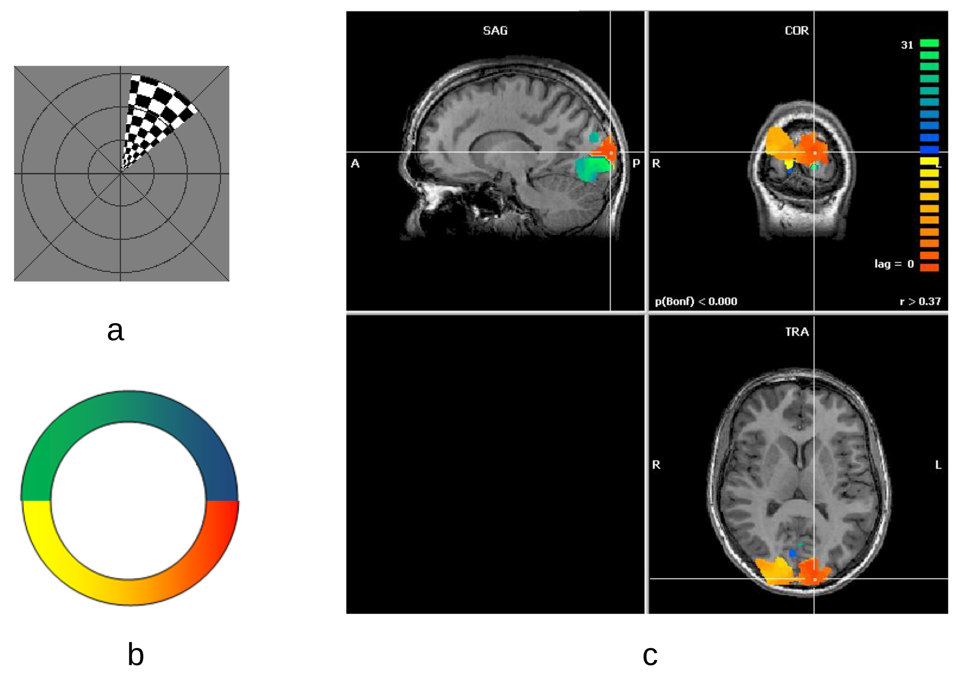

Figure 2 - (a) rotating wage (b) colour coded lags and (c) voxels corresponding to each lag

Results

We used the correlation map of unsmoothed data as the gold standard to assess the shift of activation centres by each smoothing filter. For each smoothed map, we calculated sensitivity, false negative and positive predictive value with reference to the gold standard at each lag separately. Figures 3 shows the sensitivities, false negatives and positive predictive values of 32 lags achieved by the three smoothing filters.

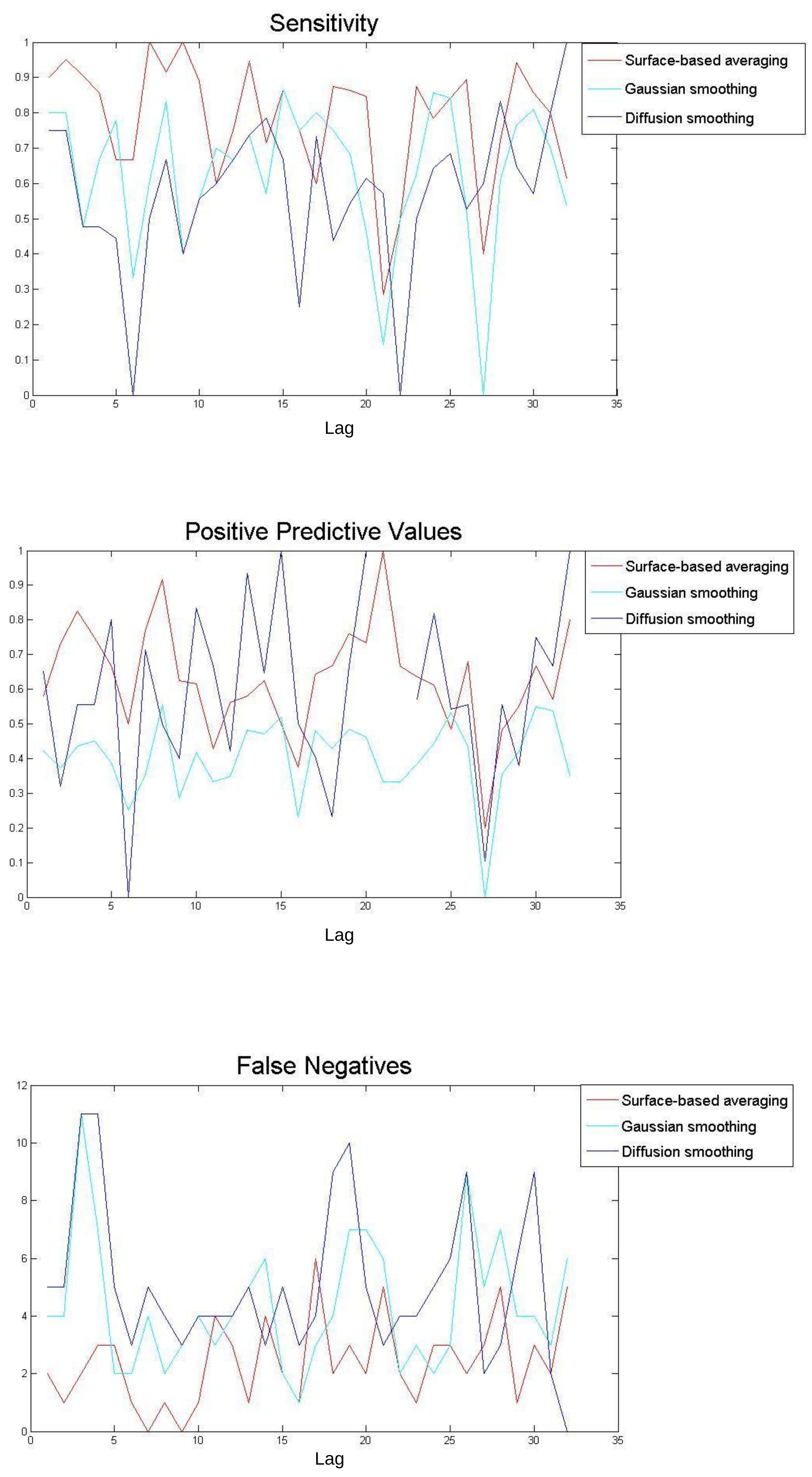

Figure 3 – Sensitivities (top), positive predictive values (middle) and false negatives (bottom) achieved for each of the smoothing filters

The Gaussian filter with FWHM=3 mm was chosen according to the recommendations for optimum values [3]. Diffusion smoothing was achieved by 10 iterations and for surface-based averaging, 4th order neighbours were included in the averaging processes.

Conclusion

Retinotopic mapping and correlation analysis of 32 areas in a small region of visual activity is very provides an ideal probe for the assessment of the smoothing filter as it is very sensitive to small shift in activation pattern.

The averaging filter shows slight improvement in sensitivity compared to Gaussian and diffusion filters. Both averaging and diffusion filters show better results for positive prediction values compared to the Gaussian filter. Least number of false negative voxels are obtained by the averaging method.

Discussion

Surface-based filters show little superiority over Gaussian filter in terms of localization and spatial resolution. However, for more pronounced improvement, certain factors such as the accuracy of registration between T1 and EPI images and grey/white matter segmentation need to be improved.

Any comparison between the smoothing filters need to be made on a number of subjects for more reliable results. We are planning to continue the study on a group of normal subjects.

References:

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3. Jascha D Swisher, John A Sexton, John C Gore, J Christopher Gatenby, and Frank Tong; "High-resolution retinotopic mapping at 7 Tesla with multishot 3D sequences"

Acknowledgements:

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