Functional Volumes Modeling using Kernel Density Estimation

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Introduction

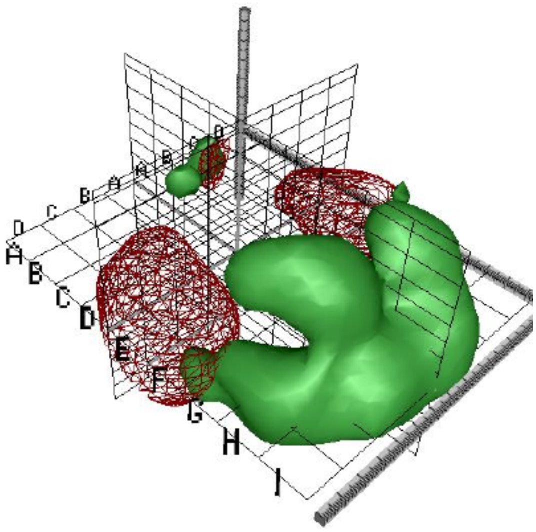
We describe a method based on kernel density estimation (also called Parzen window density estimation) for metaanalysis of brain maps, so-called functional volumes modeling (FVM) [1, 2]. We view FVM as the task of determining the conditional probability of activation foci given the design: paradigm, modality, number of subjects, etc. In [1, 2] the distribution of activation in connection with the mouth is modeled with a single Gaussian. The kernel density estimation (KDE) technique allows us to have a more flexible shape of the distribution, e.g., bimodal.

Method

KDE for FVM takes a simple multivariate distribution (the kernel) and places a local instance of it in each Talairach point. The resulting density is the sum of the local densities. We use a Gaussian with homogeneous variance as the kernel, optimizing the kernel width by leave-one-out (LOO) cross-validation. This procedure can be applied on any set of Talairach points, e.g.: The entire data from the BrainMap database [3] was downloaded from the Internet. From this data we extracted the foci and labeled those for which the field "Behavioral Domain" had only one value and were either "Audition" or "Vision", leaving 426 (60+366) 3D Talairach points. We constructed the probability density function conditioned on the label. It would be expected that the distribution of such a broad category would neither be very focused nor Gaussian. We also modeled the M1-mouth activation data assembled in [2]. The number of subjects in each experiment was not modeled.

Result

The optimization of the single parameter in the model — the kernel width — can be done fast using a Newton method. The figure shows the isosurface in the two probability density volumes rendered in 3D using VRML [4], the wireframe being for "Audition" and polygon for "Vision". The densities are not focused: With the threshold for the isosurface in the figure the probability mass within the isosurface was $P_{\text{audition}} = 0.17$ and $P_{\text{vision}} = 0.39$. The points with the highest densities for "Audition" are in the superior temporal lobe (the left area: -53,-19,4). The "Vision"-density shows a marked non-Gaussianity. Modeling the data from the foci mentioned in [2] reveals two distinct modes in the left and right M1-mouth area. It is not necessary to split the left and right set of foci before applying KDE.



Discussion

Contrary to [1, 2] we do not require any assumption of Gaussianity. On the other hand we are not able to model intersubject variability and the resulting distribution is dependent on the distribution of the number of subjects in each experiment. The ease of use of this method makes it a candidate for the set of standard techniques in FVM, where it can be used to form regions for explicit hypothesis testing in voxel-based studies. Other techniques might also be interesting in FVM: finite and infinite [5] Gaussian mixture models.

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