fMRI topographic mapping of the somatosensory cortex at 7T using multigrid priors

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Introduction: We apply a Bayesian non-parametric multiscale technique, the iterated Multigrid Priors (iMGP) method [1], to analyze high-resolution BOLD MRI data acquired at 7T to identify the regions of the cortex responding to periodic tactile stimulation of each distal phalangeal digit, allowing somatosensory topographic mapping. iMGP attributes posterior probabilities of **space and time** to the BOLD response. It is data driven and makes no assumption about the local hemodynamic response (HR) as a function of time or space. It is an extension of the MGP [2] which uses hierarchical sequences of scales to construct prior distributions by iterating down from the coarsest spatial scale to the finest one.

Data sets: High-resolution data [3] comprising 24 1 mm isotropic resolution axial slices, acquired at 7T with GE EPI, TR 2.4s, TE 25ms, 76x196 matrix, 100 dynamics was used. A piezoelectric stimulator driven at 30 Hz flutter frequency with an approximate 1mm displacement was used to deliver somatosensory stimulation. Each digit of the left hand was sequentially stimulated for 3 s, with a OFF period of 1.8 s between stimulation of adjacent digits. A whole cycle of stimulation of all five digits of the hand thus took 24 s. Digits were stimulated in a sequence from thumb to little finger (digit 1 to digit 5). Each functional scan (10 cycles; total time 240s) was repeated three times.

Functional Image Analysis: The three scans were averaged before the statistical analysis to improve the signal-to-noise-ratio. No spatial and temporal filtering was applied to the data. The iMGP method uses the fact that brain activity is to some extent localised in time and space and not restricted to isolated pixels. It involves a two stage iterative algorithm. The first stage deals with a recursive treatment of the spatial dimensions in order to obtain a posterior probability map of activity (pure MGP) and the second deals with refinements of the response model, which evolves into our estimate of HR as a function of time. We start with an initial ON-OFF model and apply the MGP method to assign a posterior probability of activity for every pixel. This set of probabilities is used to construct the posterior spatial average of time series for different regions which is only data dependent. Now this is used as new model for the next application of the MGP to obtain another posterior probability of activity and so on in an iterative fashion. The spatial representation of each digit was identified by applying the iMGP for each digit separately assuming a different phase for the initial response model. Five activity maps were then formed, one for each digit by thresholding the posterior probability. The method yields an estimate of the BOLD response per digit by constructing the posterior spatial average of time series [1]. This is done by averaging the posterior probability times the real time series over an activity region.

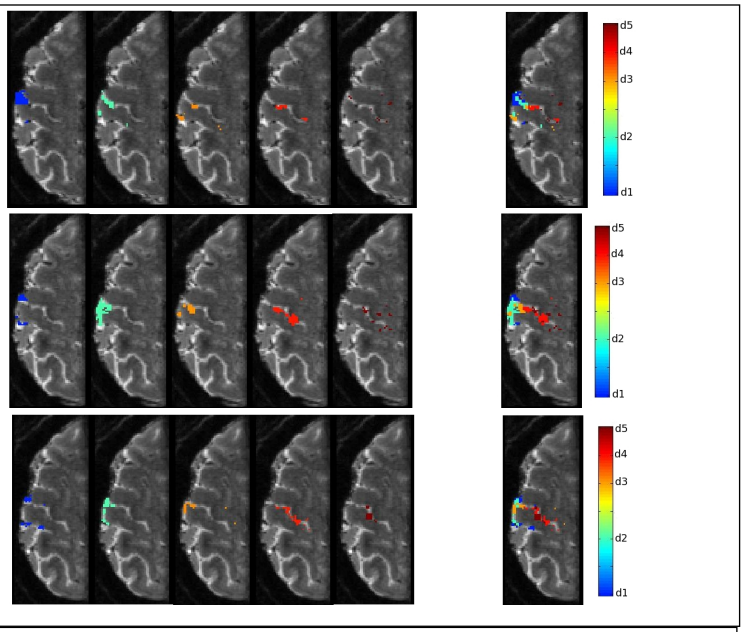

Figure 1: Resulting activity maps for the 3 contiguous slice of the same data (average of 3 scans). Left: 5 activity maps, one for each digit. Right: the five digits shown on single map. The colors correspond to different stimulated digits, d1 (thumb) to d5 (little finger). Inferior (top) to superior (bottom) slices.

Results and Discussion: Figure 1 shows the resulting activity maps for all digits from three contiguous slices. Pixels with posterior probability of activity > 0.5 are shown with a single color for each digit. Digit 1 and 2 can be seen to have the largest spatial extent within the somatotopic map, while digit 5 (little finger) has the smallest representation. At this threshold value, the maps show spatially contiguous representation of all digits, which then show segregation into subregions at high posterior probabilities. Figure 2 shows the posterior spatial average of time series for two small regions which have the shifted phases of response to stimulation. The estimate of the BOLD response as function of two cycles shows variations in magnitude and shape between regions.

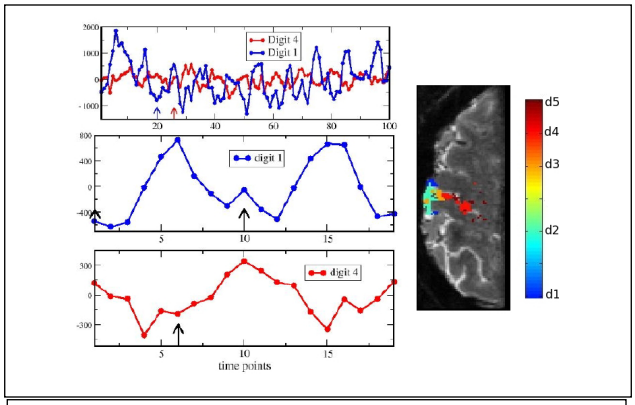

Figure 2: Posterior spatial average of time series for two digits for one slice (shown on right activity map). Right: the whole time series showing the shift in the phase between digits. Left: the HR as a function of two cycles for both digits. The arrows indicate the beginning of the stimulation.

Conclusion: We have used the iMGP method to map the digits of the hand in primary somatosensory cortex for 1mm isotropic spatial resolution data. It was able to detect an orderly pattern of response phases on the posterior bank of the central sulcus (postcentral gyrus) suggesting that the method can also be extended for retinotopic mapping studies of visual cortex. Local posterior spatial averages showed variations in HRs across digits.

References: [1] Amaral, SDR, Rabbani, SR and Caticha N. NeuroImage 36, 361-369 (2007); [2] Amaral, SDR, Rabbani SR and Caticha N. NeuroImage 23, 654-662 (2004); [3] data provided by Dr Rosa Sanchez at SPMMRC.