Bayesian approach to estimate its parameters. We extend our previously proposed integrated MEG and fMRI neural mass model to a multi-area model by defining two types of connections: the Short-Range Connections (SRCs) between minicolumns within an area and Long-Range Connections (LRCs) between minicolumns of two areas. The nonlinear input/output relationship in the proposed model is derived from the state space representation of the multi-area model. For estimating parameters of the model, we propose the variational Bayesian expectation maximization (VBEM) method which iteratively optimizes a lower bound on the marginal likelihood. Each iteration of the VBEM consists of two steps: a variational Bayesian expectation step which is implemented using the extended Kalman filter; a variational Bayesian maximization step where the posterior distributions of the parameters are inferred. For activation detection using the proposed method, the number and locations of the active areas of the brain are estimated using conventional fMRI analysis and different configurations of connections between areas are considered to construct several models. Using the proposed VBEM method, the best model is chosen among the possible models. The activation areas as well as strengths of connections between the areas are estimated. The efficiency of the proposed VBEM method is illustrated using various simulation studies as well as real MEG and fMRI data. This study proposes an efficient method to integrate MEG and fMRI and hopes to effectively use these techniques in functional neuroimaging.

6-14: Integrative Analysis for Simultaneous Spatiotemporal MEG and EEG
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Many different brain imaging modalities have been recently developed to use for brain diagnosis and basic brain research. Each brain imaging modality of them has its own weakness as well as its strong point compared to the others. Nowadays it is a hot topic in brain imaging field how brain multi-modalities can be integrated in an effective way that each may complement one another and keep its advantage. Applicatin of Bayesian inference analysis to integration of multi-modal brain imaging data could be a good tool.

In this work, Bayesian inference analysis is used to integrate multi-modal brain imaging data in the general mathematical setting. Particularly, symmetric integration for simultaneous magnetoencephalographic (MEG) and electroencephalographic (EEG) analysis is formulated. Its usefulness through various tests is verified.

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6-15: Spatio-temporal investigation of Resting State Networks through a combined fMRI-MEG study
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Recent functional Magnetic Resonance Imaging (fMRI) studies show that the topography of the spontaneous, i.e. not stimulus nor task evoked, blood oxygen level dependent (BOLD) signal is organized in functionally specific networks. The frequency of BOLD signal fluctuations is slow (< 0.1 Hz), much lower than neuronal activity. We recorded in separate sessions fMRI and Magneto EncephaloGraphy (MEG) signals in healthy human subjects (N=15) during 5-minute long periods of visual fixation alternating with periods of finger tapping. This analysis is based on 3 blocks of visual fixation (15 minutes). The MEG data were analyzed by means of a two step fast-Independent Component Analysis (ICA) approach. First, the acquired signals were decomposed into a set of ICs consisting of a spatial map of the weights and a temporal pattern. The signals were reconstructed by recombining the ICs through their weights at each voxel. Eventually, the power was computed in the band 1-150 Hz. Our analysis was based on the correlation between the temporal patterns of power in the whole brain with respect to a reference seed obtained from previous fMRI studies. We obtained a 3D correlation map that can be compared to the fMRI results. We studied the temporal evolution of the correlation of pairs of seeds included in the dorsal attention network in overlapping 8 second windows. The results showed a dynamical behavior of the network over time, elucidating how the connections among the different nodes of the network are modulated at the typical frequencies of the BOLD signals. When the whole network is found its spatial structure resembles the fMRI pattern.

6-16: Signal Processing Techniques for Multimodality Studies
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Introduction: The integration of MEG with fMRI data provides a powerful approach to study human brain function with high spatiotemporal resolution. MEG and fMRI are however recorded separately in different environments; the ability to include a common modality to ensure equivalence of brain responses is therefore attractive. Here, we apply comparable beamformer techniques to MEG data and EEG data recorded concurrently with fMRI to demonstrate this equivalence. Methods: The paradigm involved stimulating the right median nerve. A trial comprised 8s of 2Hz stimulation followed by 8s rest. The experiment comprised 30 trials. MEG data were recorded using a 275 channel CTF scanner. fMRI data were acquired using a 7T Philips scanner; EEG data were recorded concurrently using a Brain Products 64 channel system. MEG data were analysed using a beamformer approach: The evoked response was localised, and timecourses of evoked and γ-band responses extracted. Following averaged artifact subtraction to minimise MR induced artifacts, equivalent beamformer analyses were applied to EEG data. fMRI data were analysed in SPM5. Results: Results show good agreement in source localisation using MEG, EEG and fMRI. Temporal agreement between EEG and MEG suggests that despite the different environments, the response to median nerve stimulation is equivalent. Importantly, beamformers can be successfully applied to EEG data recorded at 7T and they reduce residual scanner-related artifacts. Beamformer techniques should therefore be used for residual artifact correction as well as source localisation. Conclusion: We show that EEG can be used as a common modality, and that EEG and MEG data can be processed using equivalent techniques. This methodology will be useful for cognitive studies where MEG and fMRI data are compared.

6-17: Collaborative Research around MEG Singular Infrastructures

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The high cost and complex installation of advanced MEG+MR facilities makes of them unique and high valuable shared tools for a wide spectrum research and clinical groups that can take advantage of them with different objectives. These centres can play several roles in multiple research and clinical environments. A schematic overview of the typical generic interactions and collaborations with other groups is presented, including a discussion about the importance of the synergies generated around them. Several examples of successful working neuroscience collaborations around magnetoencephalography are described.

6-18: Local sphere based coregistration for SAM group analysis in subjects without individual MRI

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Synthetic aperture magnetometry (SAM) is a powerful MEG source localization method to analyze evoked as well as induced brain activity. To gain structural information of the underlying sources, especially in group studies, individual MRIs are required for coregistration. During the last few years the relevance of MEG measurement on understanding the pathophysiology of different diseases has noticeable increased. Unfortunately, especially in patients and small children, structural MRI scans can not always be performed. Therefore we developed a new method for group analysis of SAM results without requiring structural MRI data which derives its geometrical information from the individual volume conductor model constructed for the SAM analysis. The normalization procedure is fast, easy to implement and integrates seamlessly into an existing landmark based MEG-MRI coregistration procedure. This new method was evaluated on a pneumatic index finger stimulation paradigm analyzed with SAM on eight subjects. Compared to an established MRI based normalization procedure (SPM2) the new method shows only minor errors in single subject results as well as in group analysis. The variation between individual subjects was found generally higher than the error induced by the missing MRIs. The method presented here is therefore sufficient for most MEG group studies. It allows accomplishing MEG studies with subject groups where MRI measurements cannot be performed.

6-19: Magnetic resonance imaging using sensor arrays of SQUIDs and by polarization encoding

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In magnetic resonance imaging (MRI), signals can be encoded using a dense array of sensors with different spatial sensitivity profiles. Mathematically, the mapping from sources to sensors can be described as \( s(t) = Am(t) \), where \( s(t) \) is a signal vector, \( A \) is a lead field matrix, \( m(t) \) is a source vector containing the components of the magnetic moments of the sample voxels, \( t \) stands for time, and the presence of noise is omitted. From this equation, it is impossible to solve...
Abstract / Poster: 7 Inverse/Forward modeling and solution (1)

precisely more elements of \( m(t) \) than the number of linearly independent rows in \( A \), i.e., the rank of \( A \). We present a method that by performing consecutive measurements with different polarizing fields, it is possible to construct a signal vector \( s^?(t) \) and a matrix \( A^? \), which has a higher rank than \( A \). The key of the method is to choose consecutive polarizing fields such that \( m_i(t) = C_i m(t) \), where \( m_i(t) \) is a source vector of the ith measurement and \( C_i \) is a conversion matrix of the ith measurement. A larger matrix \( A^? \) is produced by combining \( A^i \)'s row-wise; if the conversion matrices are chosen properly, the rank of \( A^? \) can be made higher than \( A \). Similarly, \( s^?(t) \) is obtained by combining the signals \( s_i(t) \) from successive measurements. As a result, \( m(t) \) can be solved more accurately than using only \( A \). Low-field MRI offers possibilities for realizing the proposed method, because the polarizing fields are reasonably low and can be altered easily. Potential \( C_i \)'s are obtained, e.g., by rotating the polarizing field or by using various polarizing gradients.

Poster: 7 Inverse/Forward modeling and solution

7-1: A Distributed Spatio-Temporal EEG/MEG Inverse Solver

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We propose a novel L1L2-norm inverse solver for estimating the sources of EEG/MEG signals. Developed based on the standard L1-norm inverse solvers, this sparse distributed inverse solver integrates the L1-norm spatial model with a temporal model of the source signals in order to avoid unstable activation patterns and "spiky" reconstructed signals often produced by the original solvers. Furthermore, the joint spatio-temporal model leads to a cost function with an L1L2-norm regularizer whose minimization can be reduced to a convex second-order cone programming (SOCP) problem and efficiently solved using the interior-point method. Validation with simulated and real MEG data shows that the proposed solver yields source time course estimates qualitatively similar to those obtained through dipole fitting, but without the need to specify the number of dipole sources in advance. Furthermore, the L1L2-norm solver achieves fewer false positives and a better representation of the source locations than the conventional L2 minimum-norm estimates.

7-2: New iterative localization method for distributed source model using combined MEG and EEG

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The conventional MEG instruments allow the simultaneous recording of magnetic fields and electrical potentials on the scalp. Since MEG cannot detect the radial component of the neuronal current and EEG responds little to the closed loop current, in the clinical experiments the signal is frequently detected by only one of MEG or EEG. In the present source localization methods using MEG and EEG, the fusion does not cause a cooperative effect but only puts results of MEG and EEG together which is nothing but an increase of the number of measured data. Moreover, the fusion systematically tends to spoil the performances of the other one without any consequent improvement. In this research, we propose a new method for a cooperative process of MEG and EEG. First, we modify the adjoint state approach to the inverse problem and propose a new method using combined MEG and EEG. The method is to solve the minimization problem iteratively by a descent algorithm using the gradient of a Lagrangian which is consisted by the measurement error functionals of measured data and constraining terms. In order to achieve the synergy effect cooperatively, the constraints consider interactions of the directional and geometrical properties of MEG and EEG and we adjust the influence ratio of the data to preserve the each performance. This new method brings major improvement to localize undetected active source region and handle the disagreement of reconstructed solutions with reduction of sensitivity to perturbation on MEG or EEG. Moreover, the solution of the iterative method converges stable to a source distribution compared to another iterative one, FOCUSS which requires stopping the iteration artificially for a reasonable solution.

In the verification of the new method will be carried through the comparison to the conventional methods with the interictal MEG/EEG signal of epileptics in the sense of the spatio-temporal resolution.