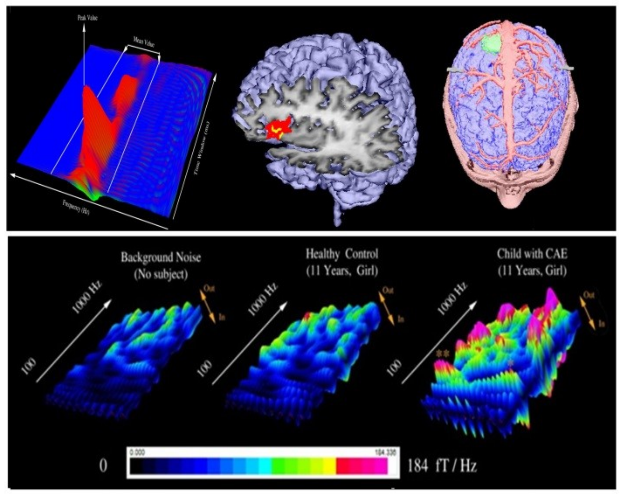
MEG Processor

(Jing Xiang, 1991-2013)

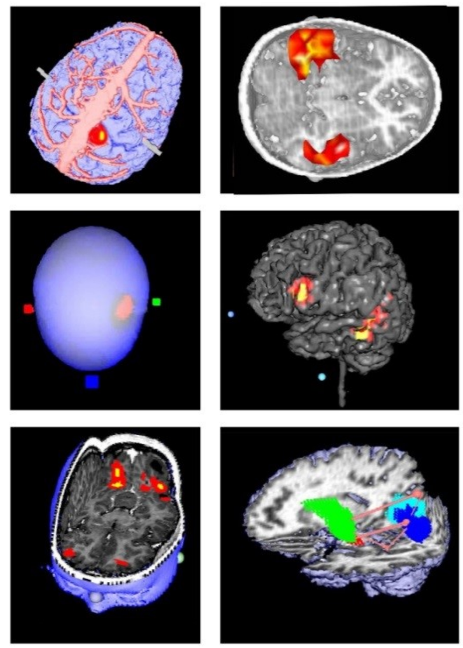
MEG Processor is a software package with new techniques for imaging functional brain activity. The neurophysiological principle of the new techniques is that MEG/EEG signals are generated by hierarchical groups of cells; low-frequency signals are generated by large groups of cells and high-frequency signals are generated by small groups of cells. The core mathematical algorithm is to spatiotemporally and spectrally decompose multi-frequency signals in MEG/EEG data to volumetrically reconstruct brain activity (cell assemble imaging, CAI). This software program also integrates multiple complementary imaging modalities (EEG, MEG, MRI and CT) in a single package and environment. By combining the latest techniques for determining magnetic and electrical activity in the brain with anatomical and functional imaging, the program provides a powerful new method for accurately reconstructing the source of such activity. The program uses the full physical anatomy from MR and CT to provide three-dimensional models of the head and brain, volumetrically delineating the site of activity. The novel functionalities make it suitable for wider applications.



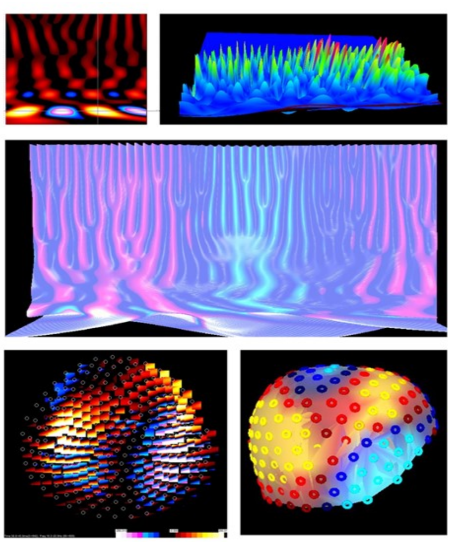
HIGHLIGHTS

- New imaging technology based on spatiotemporal and spectral reconstruction of assembled neural activation.
- Volumetric source reconstruction of elicited/evoked activation and endogenous brain activity.
- Accumulated source reconstruction with realistic boundary and finite element models.
- Statistically verifying source activity with multi-encoding technology.
- Quantitatively measuring high-frequency MEG/EEG signals in multi-frequency ranges.
- Advanced time-frequency analysis at both sensor and source levels.
- Coherence/correlation analyses at both sensor and source levels.
- GPU accelerated rendering of 3D MRI/CT and multi-core parallel dynamic source imaging.
- Integration of MEG/EEG and MRI/CT, from single trial to multi-datasets to grand operations.
- Pattern/event recognition: spike detection, template-based event matching.
- Complete data visualization: 2D and 3D, static and dynamic, color coding and overlapping.
- Tools for processing all kinds of medical 3D images (co-registration, segmentation, meshing).
- Optimized real-time rendering of 3D sources in multi-time window and frequency bands.
- Principal and Independent Component Analysis (PCA, ICA).
- Complete data processing (e.g. filtering, averaging) and online updates.
- Import wizard (drag-drop) and export of result in text, Excel and Matlab format.

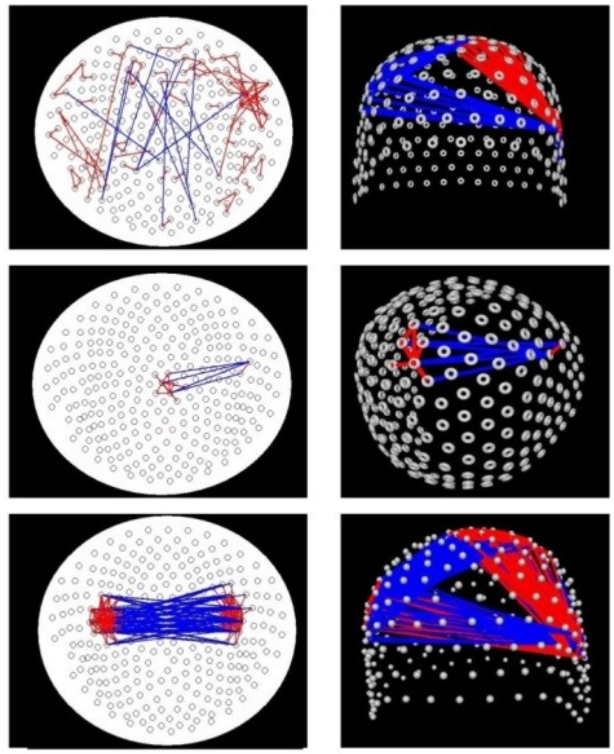
New imaging technology based on spatiotemporal and spectral reconstruction of brain activation: this program can perform source reconstruction using the well-known spherical shell volume conductor models. However, one of its unique and powerful features is to generate high-resolution volumetric source images with newly developed algorithms. The new algorithm reconstructs source patterns/patches instead of dipoles or points. The patterns are based on a regular 3D grid and the pattern values are reconstructed by decomposing MEG/EEG data in multi-frequency ranges at a time window. The software automatically calibrates the regularization parameters without needing users to make subjective assumptions of the number of sources or possible locations. Anatomical constraints can be applied but are optional. Brain activity may be originated mainly from the gray matter, the source of the cortex; the use of anatomical constraints may be useful. The software has built-in procedures perform fully automatic segmentation of the gray matter using MRI data.



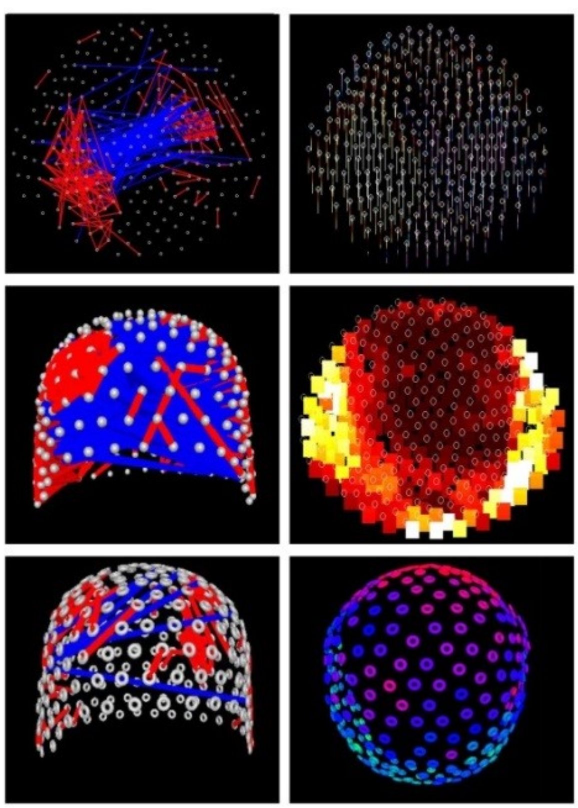
Volumetric source reconstruction of elicited/evoked activation and endogenous brain activity: Similar to 3D MRI/CT data, the reconstructed MEG/EEG source imaging is volumetric source data, which are typically color coded (red-yellow or blue-cyan). The program can perform source reconstruction using the well-known spherical shell volume conductor models. The software can work with individual anatomical data. If no anatomical data are available, the program can use its built-in gross average MRI data sets. Though MEG/EEG source data are typically based on fiducial-defined 3D coordinates, the program does support Talairach coordinates and atlas. By specifying AC, PC and the brain extensions, source data can be transformed into Talairach coordinates and extensive anatomical and functional atlas information (Brodmann areas) can be assessed. Activation time courses for volumetric source can be displayed on 2D and 3D viewers simultaneously.



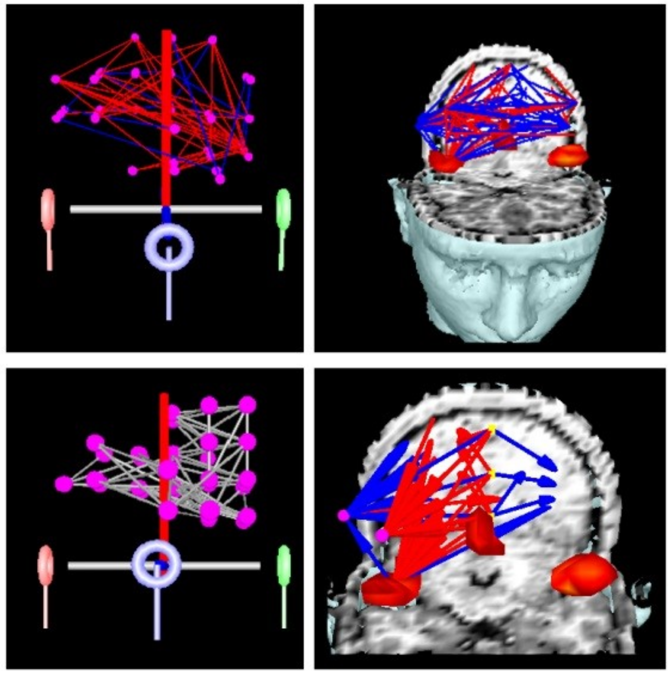
Advanced Time-Frequency Analysis Methods: Time-frequency analysis can reveal the event-related time-locked or induced cerebral activity in the time-frequency domain. Time-locked activity, event-related signals with similar wave shape over trials, can be extracted by real-time averaging. Induced activity, oscillatory activity occurring in a certain event-related time window with varying time lag and phase, can be extracted by time-window accumulating. Event-related synchronization (ERD) or de-synchronization (ERS), or temporal spectral evolution, can be visualized in 2D and 3D spectrograms, which represent the change in power or magnitude over time.



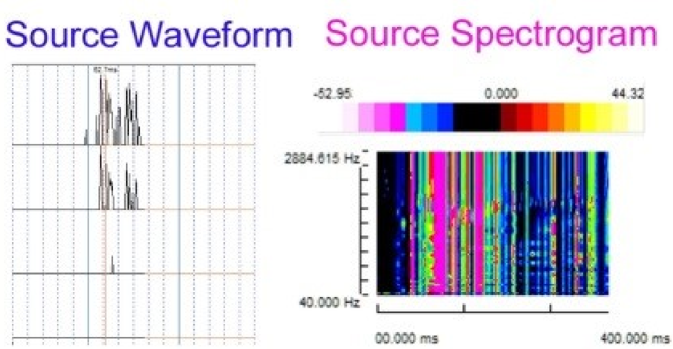
Waveform CxC: To quantitatively determine the relationship (e.g. correlation and covariance) between channel-pairs, an optimized channel-cross-channel matrix has been developed. Correlation describes the relationship between two time signals, i.e. scalar product of normalized time signals in time domain. Since filters are typically applied to waveform data, the correlation represents the relationship of amplitude of signals in a predefined frequency range and time window. When correlation/covariance is calculated at MEG sensor pair/EEG channel pair, activity from various brain regions is picked up in a group of sensors/channels. Oscillatory activity in one brain region can already lead to a strong coherence between some sensor/channel pairs because of the wide distribution of focal brain activity at the brain surface. This is due to the nature of the dipole fields when recording remotely and due to the smearing effect of the volume conduction in MEG/EEG. As a consequence, a correlation/covariance measure between surface sensors/channels cannot distinguish between coherence due to propagation and real coherence between the oscillatory activities in two coupled brain regions. Whether true coherence can be detected at the scalp depends mainly on the relative orientation of the source currents in the underlying brain regions and, to a lesser extent, on their distances in location.

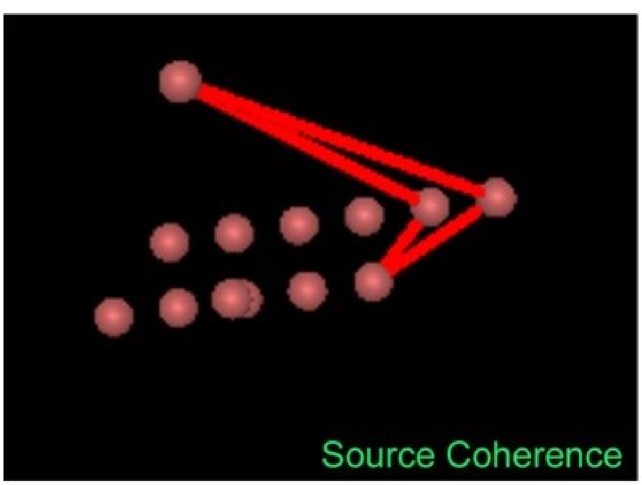


Spectral CxC: the software includes the multichannel spectral analysis, brain mapping and coherence. Power spectra and coherence can be computed for any selected part of recorded MEG/EEG. Different parameters of spectra computed for predefined frequency band ranges can be displayed as histograms, maps and tables. The relationship of every sensor/electrode pair can be described as spectral-temporal density function, which is amplitude of signals at a certain frequency f and interval t relative to an event. Coherence indicates correlation of two spectral density functions over trials, i.e. squared scalar product of two spectral density functions over trials, normalized across all trials. Phase locking value (PLV) describes correlation of two normalized spectral density functions over trials. Amplitudes are neglected, only phase relationships between two oscillations are considered.

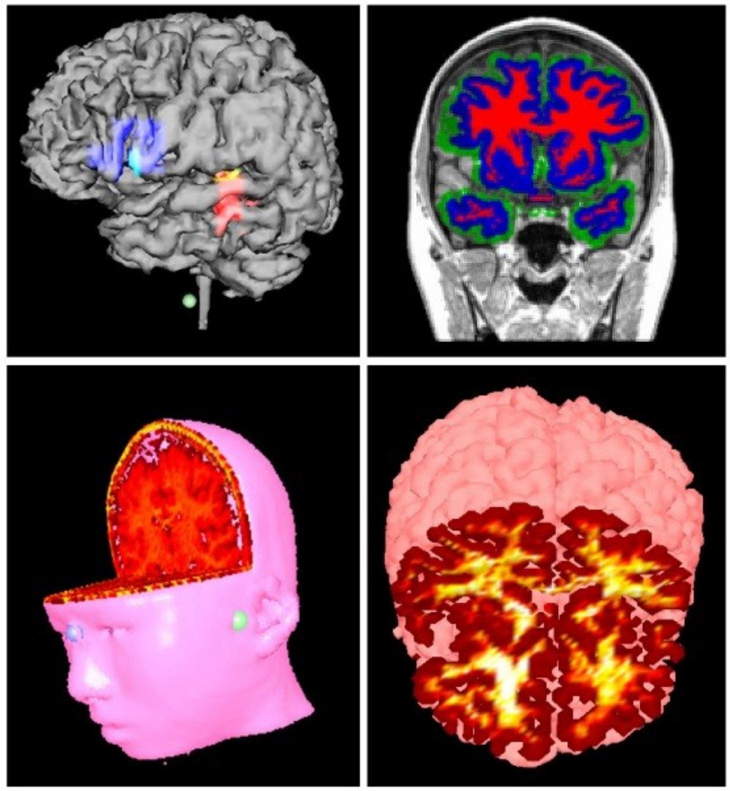


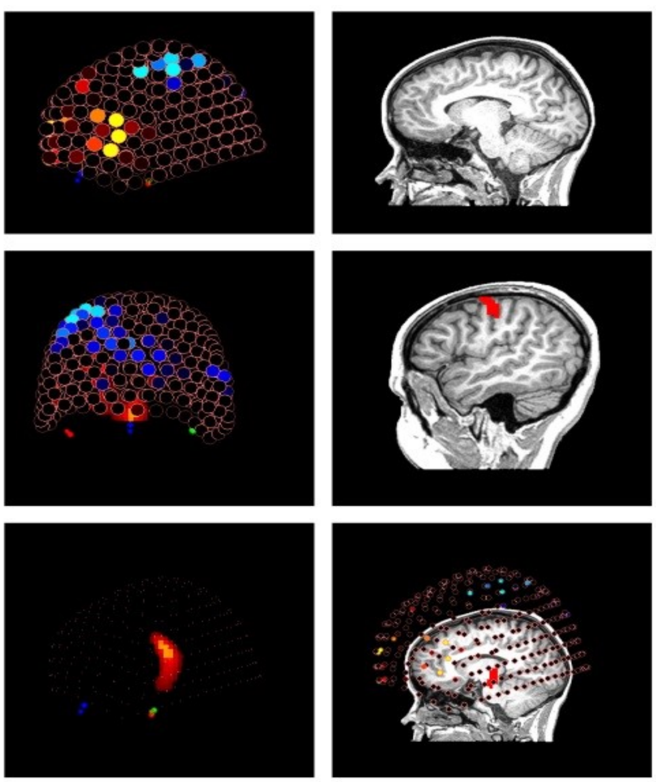
Neural Network (Volumetric Source Coherence): neural network was traditionally used to refer to a network or circuit of neurons. The usage of the term in this software often refers to the relationship of two source pairs. Therefore, neural networks, which are composed of sources or nodes, refer to biological neural networks, made up of real biological neurons. Whether you are using a single subject or a group design, the measurements (source power in source imaging) can be recorded in an independent editor and exported as a text file for testing of statistical measures of significance in your data.





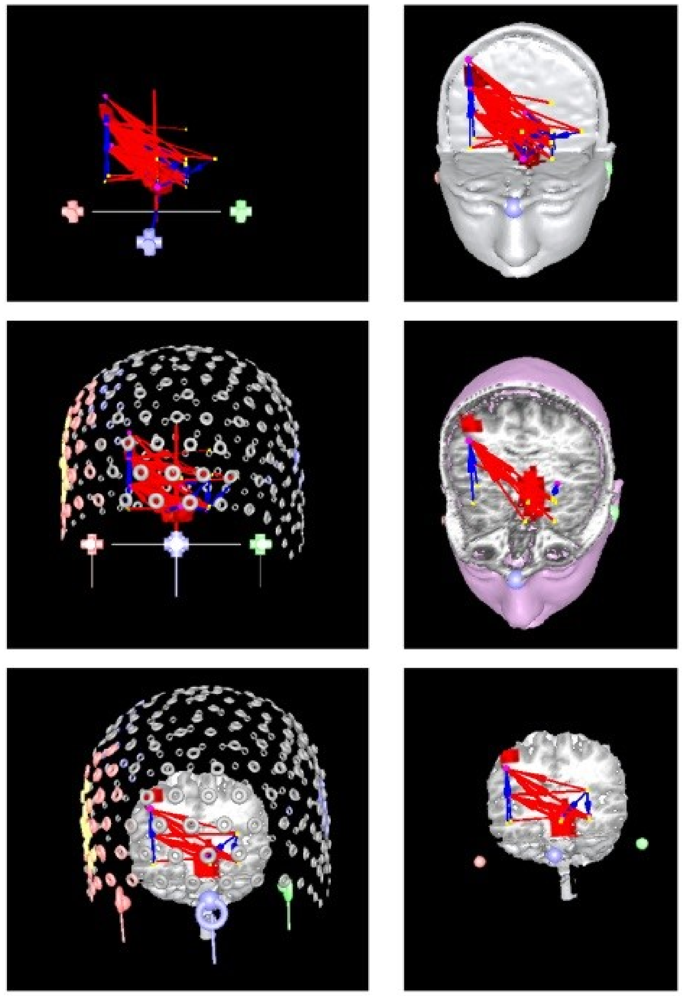
Virtual Sensor (source waveform, spectrum and coherence): A virtual sensor estimates waveform/spectral properties or processes conditions using mathematical models rather than physical sensors/electrodes. These mathematical models use other physical sensor readings to calculate the estimated properties or conditions of brain activity. Whether you are using a single subject or a group design, the measurements (e.g. source amplitude and latency in waveform, spectral power in spectrogram, source coherence) can be recorded in an independent editor and exported as a text file for testing of statistical measures of significance. In this software, virtual sensors are used differently from **virtual channels (VC),** which are typically generated by an operation applied to two or more channels (e.g. subtraction of two channels or the average of a group of channels around a positive peak is subtracted from the average of a group of channels around the negative peak).





MRI/CT Segmentation: The software has a set of automatic tools for reconstruction of the brain from structural MRI/CT data by segmentation. Segmentation can be done by many software tools. The tools can extract the representation of the cortical surface between white and gray matter, representation of the pial surface, segmentation of white matter from the rest of the brain, skull stripping. In addition, the software can create computerized models of the brain from MRI/CT data, integrate MEG/EEG sources into MRI/CT data, measure a set of morphometric properties of the brain including cortical thickness and regional volumes, inter-subject averaging of structural and functional data. In addition, the software has a built-in function for MEG/EEG-guided identifying of subtle MRI abnormalities.

MSI 2D Viewer (pixel wise analysis): Optimized 2D Viewer of sophisticated integration of MEG/EEG and MRI/CT data. The software enable users to investigate voxel-wise changes in the grey matter volume/topography in one population related to one clinical score, or between several populations. Importantly, the software can directly compare and measure whether the activations or abnormalities seen in MEG/EEG are possibly caused by structural abnormalities with advanced color-coding technology. To be able to compare all the images on a voxel wise basis, they need to be transformed into a standard space. The interpretation of the MEG/EEG or MRI/CT results has inherent limitations, the combination of MEG/EEG and MRI/CT provide unique advantages in the interpretation of image findings. For example, the concordant of MEG/EEG and MRI/CT findings may help clinicians determine epileptogenic zones in clinical practice.



MSI 3D Viewer (Dynamic MSI): Optimized 3D Viewer of sophisticated integration of MEG/EEG and MRI/CT data. The software contains almost everything you need for the advanced analysis and visualization of MRI/CT data and MEG/EEG distributed source imaging. In addition, it provides animal brain imaging and neural network simulation. 3D mapping of data can be performed by software to which mapped data is transferred automatically.

Quantitative Measurements and Statistical Analysis: The waveform, spectra, coherence, ERP, ERD and source data can be processed in automated mode for collection of recordings selected by the user. The results of processing can be automatically stored to a build-in database. Whether you are using a single subject or a group design, the measurements (amplitude and latency in waveform, spectral power in spectrogram, and source power in source imaging) can be recorded in an independent editor and exported as a text file for testing of statistical measures of significance in your data. This software support multi-dataset and trials, there are build-in statistical analyses such as Topographic Analysis of Variance (TANOVA). TANOVA uses assumption-free randomization statistics, which make fewer assumptions than classical parametric tests and are therefore more robust.

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