Introduction to Source Analysis –
Distributed Source Imaging using LORETA

BrainVision Analyzer 2 Webinar

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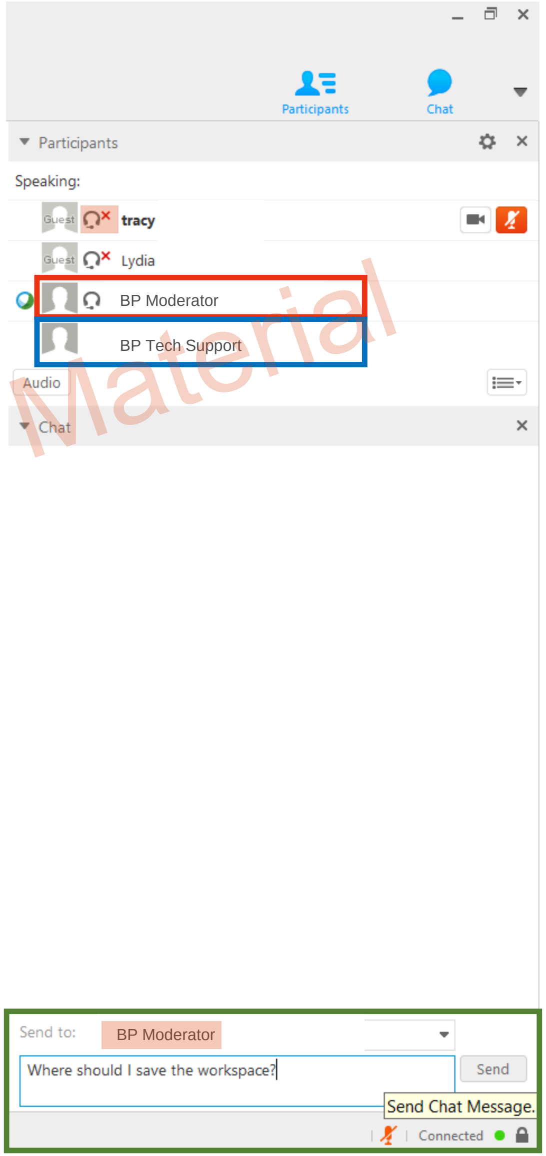
Webinar procedure

Please ask questions only via the chat window:

- Questions related to Webinar content should be addressed to BP Moderator.
- Questions related to technical issues (video, sound) should be addressed to BP Tech Support.

Questions will either be answered directly or compiled for the open questions in the end.

Please ensure that your microphones are muted and that you do not start video streaming with your webcam.



Objectives of this webinar

Goals

- Theoretical background of Source Analysis
- Source Analysis using LORETA in Analyzer 2

Learning Outcomes

- Make use of LORETA's functionality in your processing pipeline
- Data post-processing in the source domain

Outline of the session

1. Theoretical background of Source Analysis
   - Why Source Analysis?
   - Principles of the Forward and Inverse problem

2. Theoretical basis of LORETA
   - Assumptions and constraints

3. Implementation of LORETA in Analyzer 2
   - Ingredients of LORETA
   - Data post-processing in the source domain
   - Limitations of LORETA
   - DOs and DON'Ts of LORETA in Analyzer 2

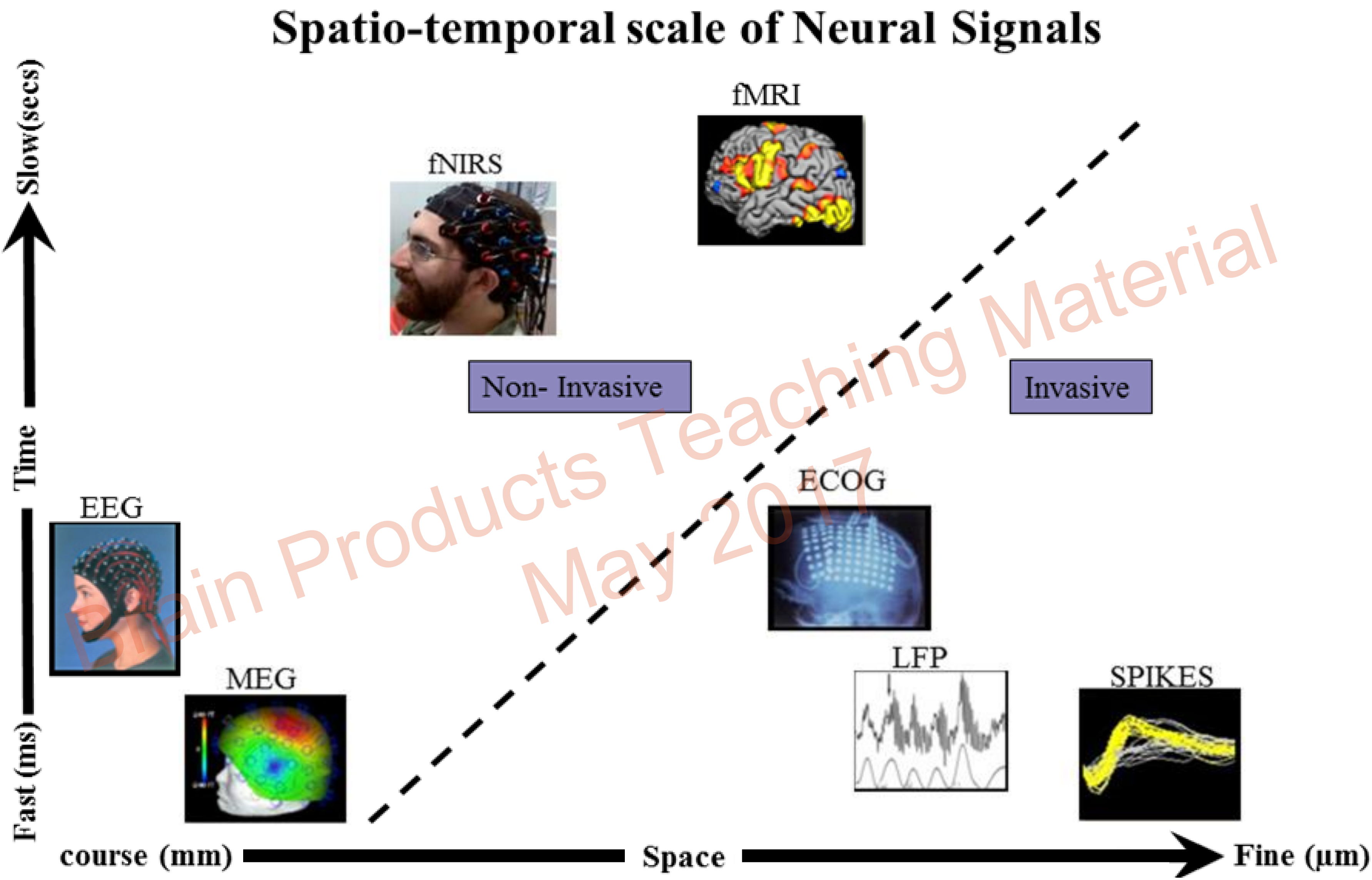
4. Open Questions

5. Concluding Remarks

1

Theoretical background of Source Analysis

Multimodality → Why EEG?



adapted from Kim YJ (2015) A study on a robot arm driven by three-dimensional trajectories predicted from non-invasive neural signals.

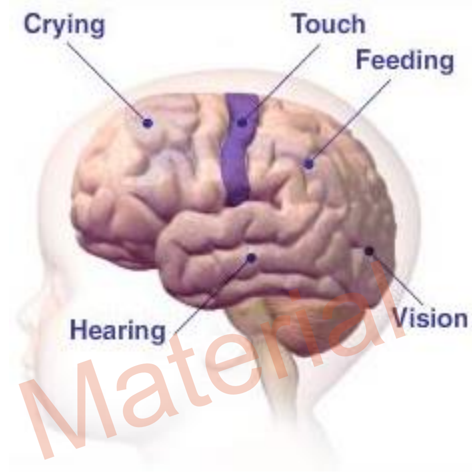
Comparison: EEG vs fMRI

	EEG	fMRI
Temporal resolution	Excellent (milliseconds)	Poor (seconds)
Spatial resolution	Poor (cm)	Excellent (mm)
What does it measure?	Electrical activity (direct)	Metabolic activity (non-direct)
Mobility	Portable	Non-portable
Price	Affordable	Expensive

EEG → Superior temporal resolution with the cost of inferior spatial resolution!

Aim and Applications

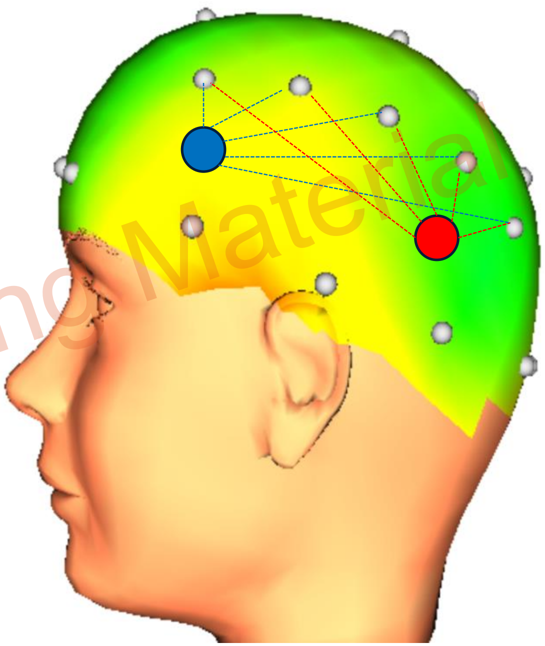
- Aim
  - To find the source of the brain activity by analyzing the electrical activity recorded from surface electrodes.



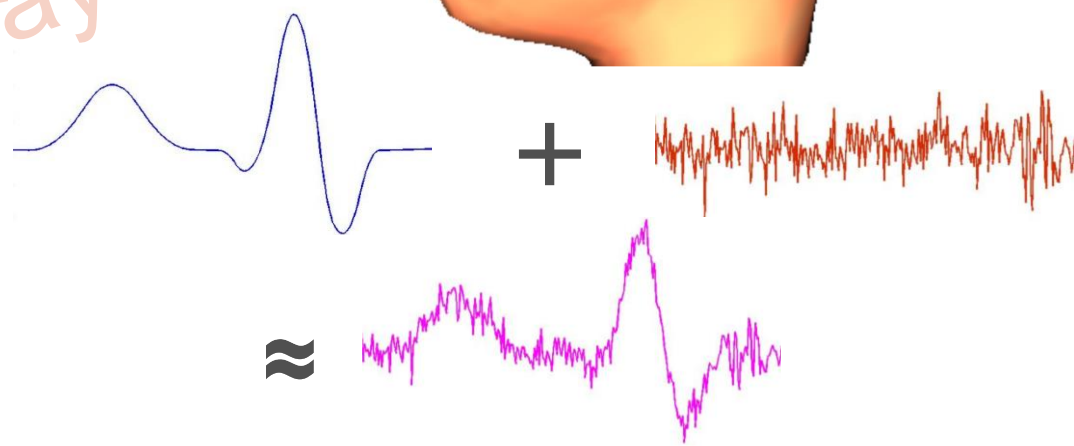
- Applications
  - Well-known experimental paradigms:
    - Resting state ongoing responses (1).
    - Auditory evoked potentials (2).
    - Somatosensory evoked potentials (3).
    - Cognitive event related potentials (4).
    - Spikes and/or Seizures (5).

Why Source Analysis?

- EEG is a non-invasive measurement of macroscopic, reference-dependent observables of brain activity.
- EEG dynamics reflects the superposition of many neuronal systems distributed across the brain.



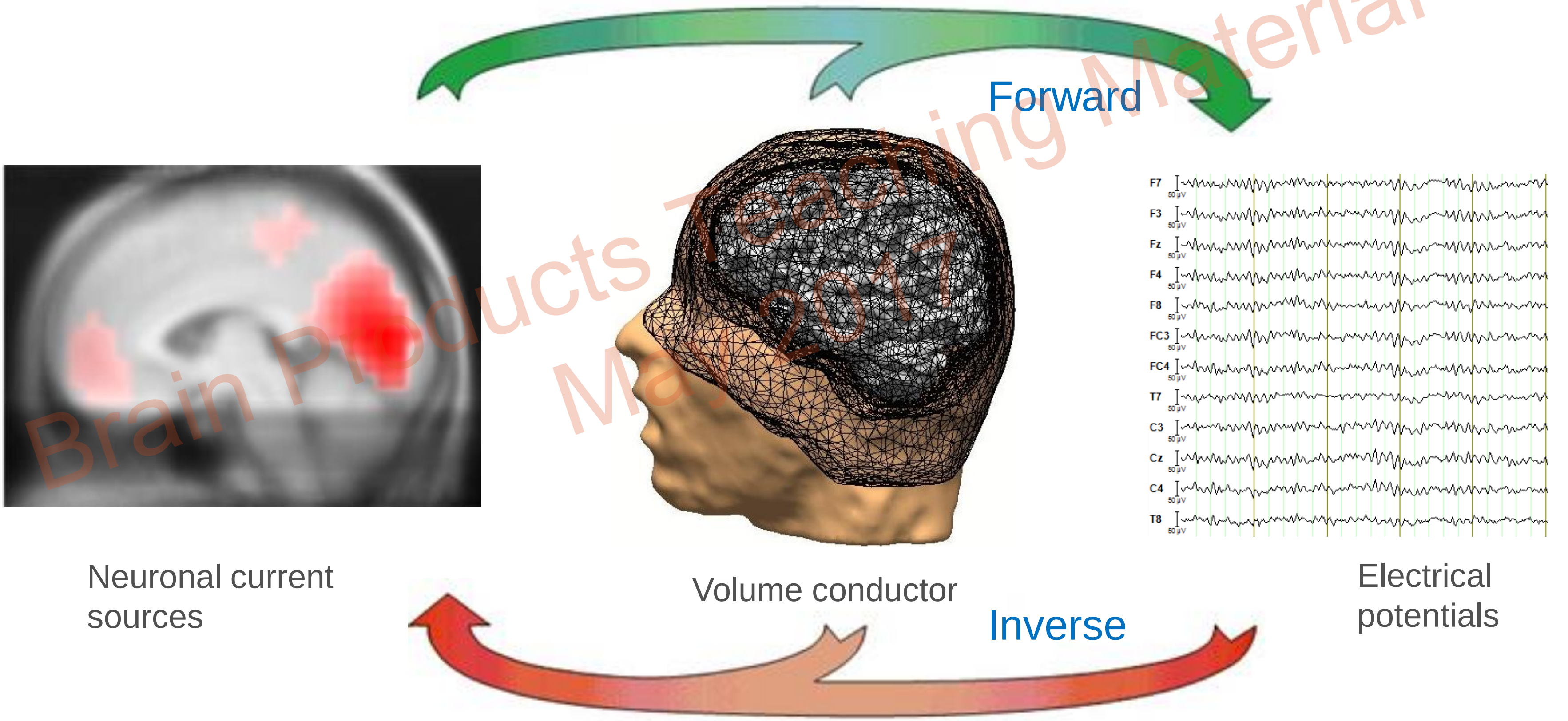
- Source Analysis is the approach to:
  - achieve a reference-free data representation.
  - decompose EEG patterns into its underlying neuronal sources.
  - localize the sources of EEG activity within the brain.



Ingredients of Source Analysis

- Forward modeling

- Inverse modeling



Ingredients of Forward Modeling

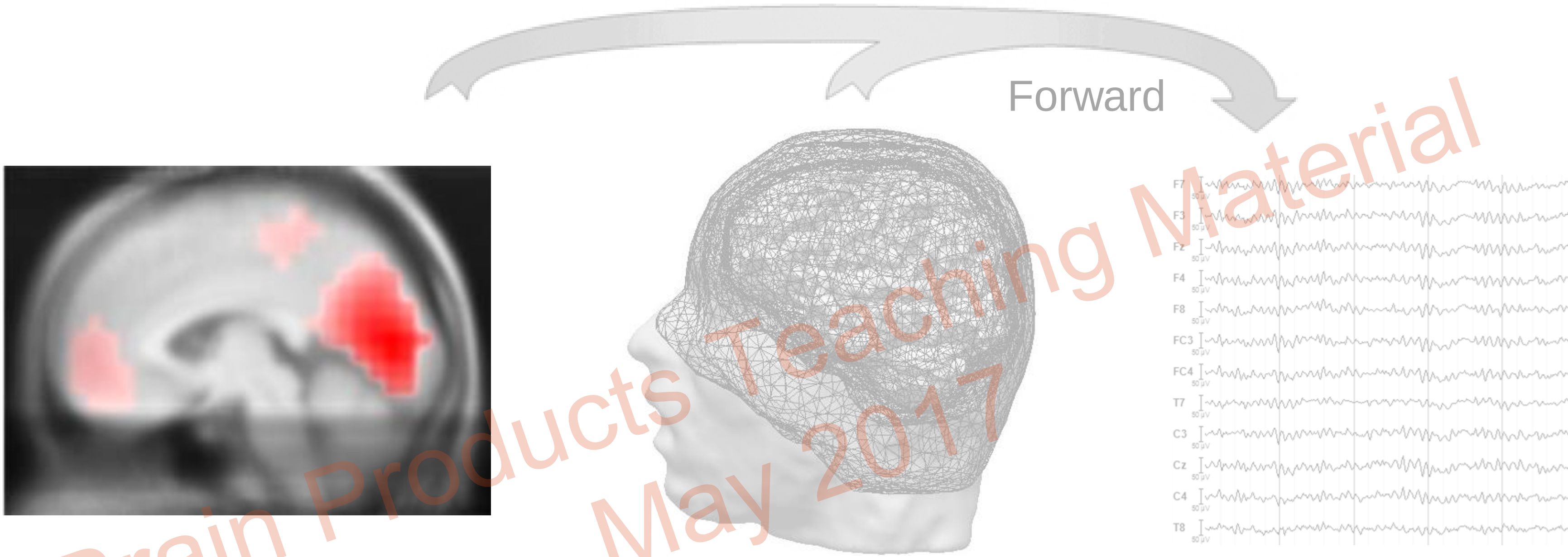
(1) Source modeling

(2) Anatomical modeling

(3) Head modeling (volume conductor models)

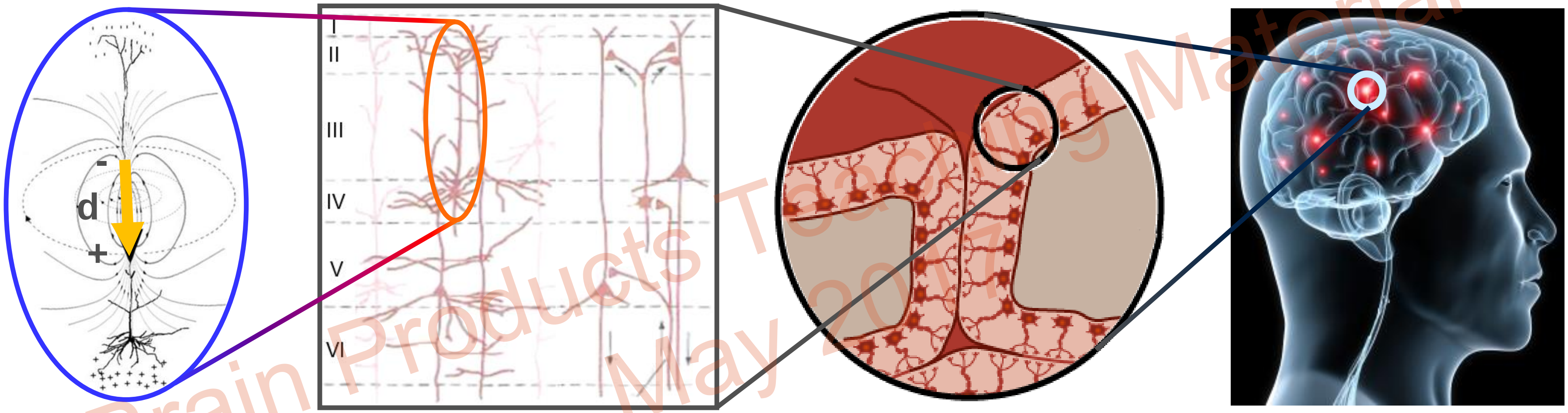
(4) Coordinate transformation (co-registration)

(1) Source Modeling

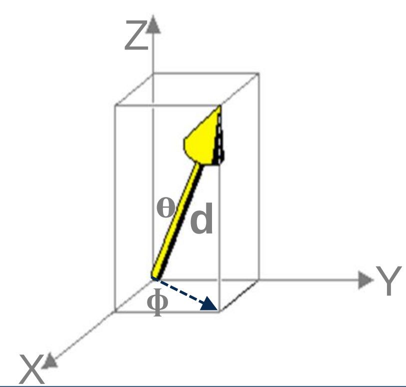


Forward Problem: Source Modeling

- Oscillations arise from the interplay of many neural ensembles through excitatory and inhibitory synapses.
- Primary current sources representing a focal area of synchronously active pyramidal cells can be modeled using equivalent current dipole.

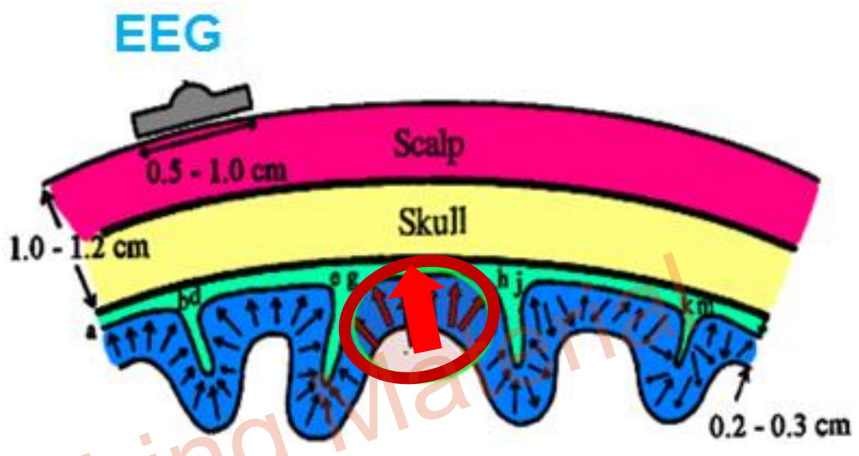


- A dipole is characterized by its **6** parameters:
  - **3** for its location,
  - 3 for its vectoral components in Cartesian coordinates:
    - **1** magnitude and **2** orientations expressed in spherical coordinates.



Forward Problem: Source Modeling

- A source model can be based on:
  - a single dipole.
    - Representing neural ensemble.
  - multiple/distributed dipoles.
    - Each dipole represents a small cortical patch.



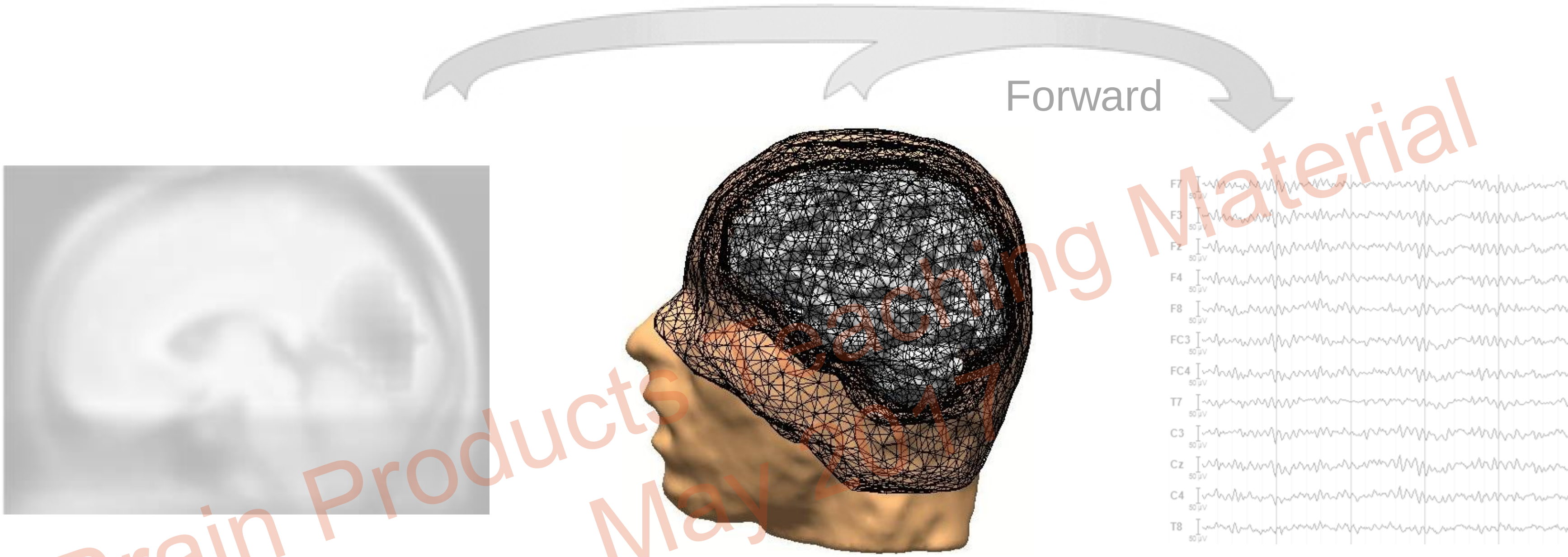
$$\vec{J}_{(3x1)} = \begin{bmatrix} J_x \\ J_y \\ J_z \end{bmatrix}$$

For single source

$$J_{(3Mx1)} = \begin{bmatrix} \vec{J}_1 \\ \vec{J}_2 \\ \vdots \\ \vec{J}_M \end{bmatrix}$$

For M sources

(2) Anatomical and **(3)** Head Modeling



Neuronal current sources

Volume conductor

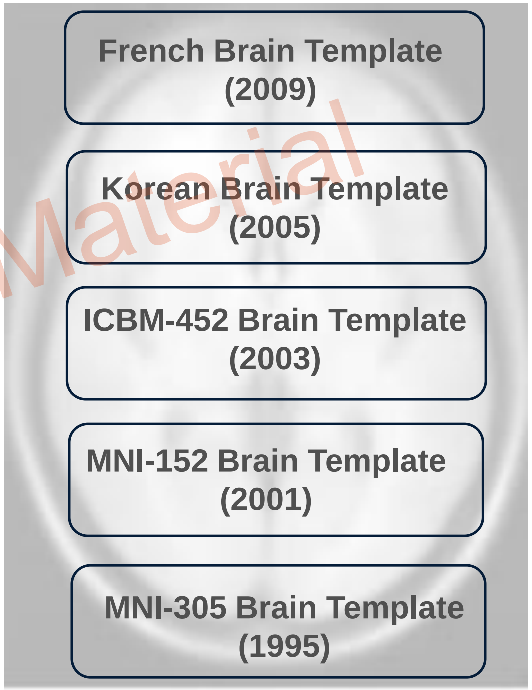
Electrical potentials

Determined by:

- Anatomical modeling and
- Head modeling

Forward Problem: Anatomical Modeling

- Brain volume, shape and size vary across different people.
  - Standard brain template.
    - A brain template is an anatomical representation depicting finer anatomical details.
    - Generated either from:
      - a single representative subject or
      - multiple subjects → have higher signal-to-noise ratio and provide better contrast between grey and white matter.
    - Help in performing comparative analyses by transforming each of the individual's structural data to a well-established template → report results in standard coordinate system (e.g., MNI space or Talairach and Tournoux space).
  - Realistic (individual) brain.
    - Whole head T1 weighted MR of a particular subject.



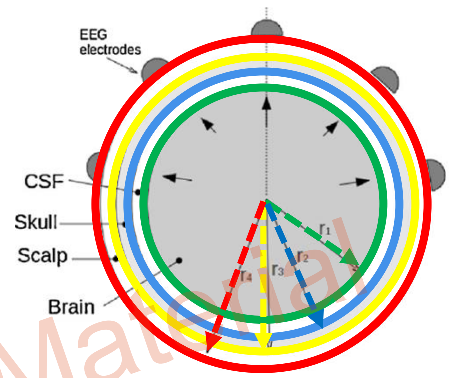
- **Chinese Brain Template (2010)**
- **French Brain Template (2009)**
- **Korean Brain Template (2005)**
- **ICBM-452 Brain Template (2003)**
- **MNI-152 Brain Template (2001)**
- **MNI-305 Brain Template (1995)**
- **Talairach and Tournoux (1957,1967,1988)**

Most commonly used brain templates for adults

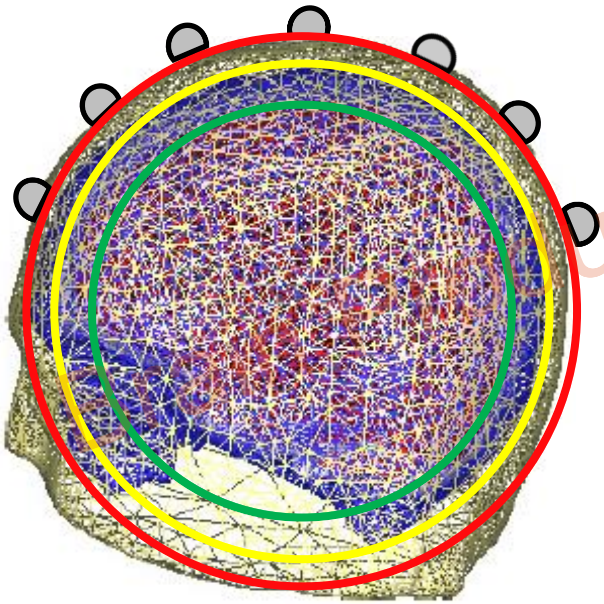
Forward Problem: Head Modeling

adapted from Nunez PL, Srinivasan R. (2006) Electric fields of the brain.

- Head volume conductor models:
  - spherical head model:
    - single layer sphere.
    - 3-4 layer concentric spheres.

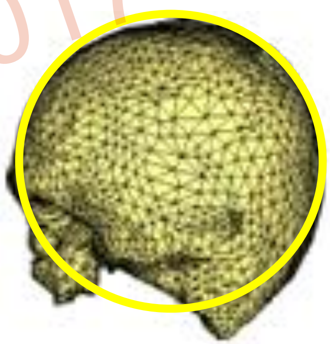


4-shell Spherical Model Brain/CSF/Skull/Scalp

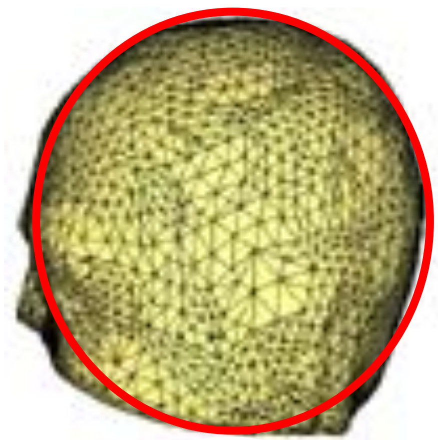


3-shell Spherical Model Fitting the MNI Brain

Brain



Skull



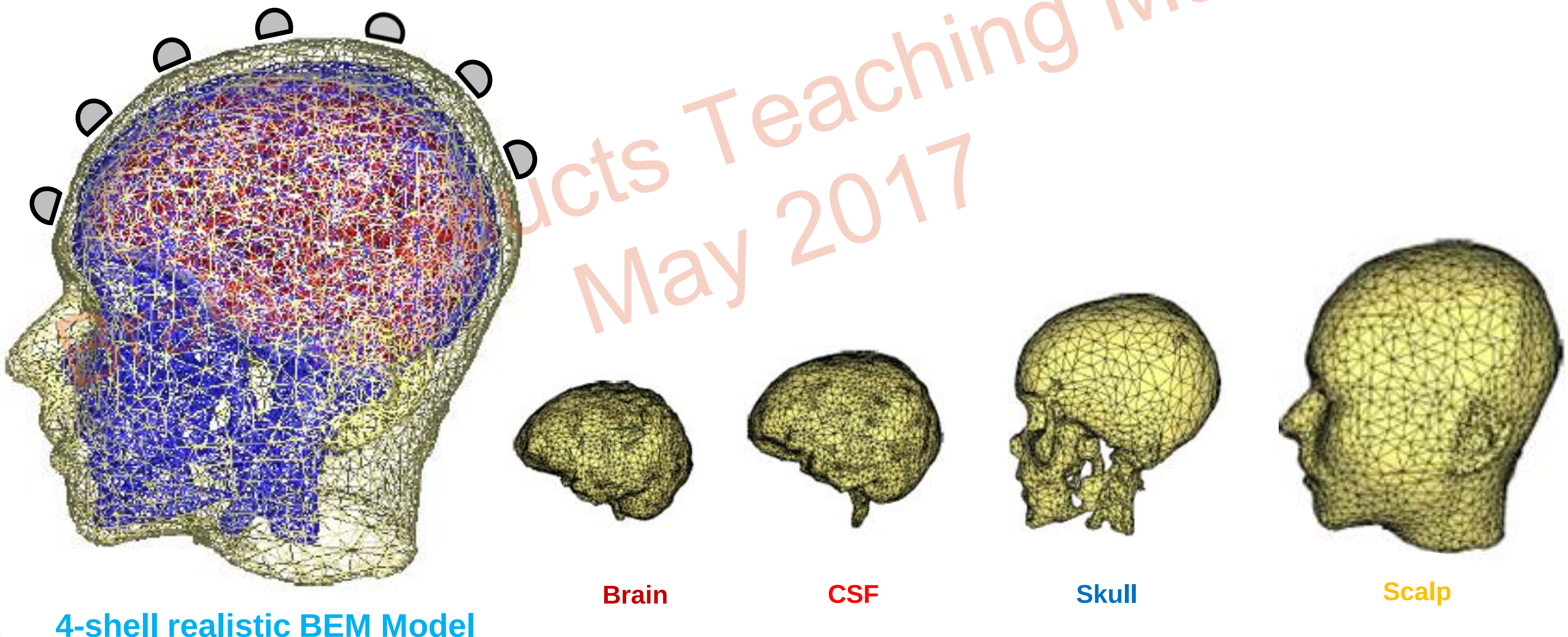
Scalp

adapted from Acar ZA (2013) Effect of forward model errors on EEG source localization.

Forward Problem: Head Modeling

- Head volume conductor models:
  - realistic head model:
    - Boundary-Element-Method (BEM): assumes isotropic tissue conductivities.
    - Finite-Element-Method (FEM)
    - Finite-Difference-Method (FDM)

    } anisotropic tissue conductivities.



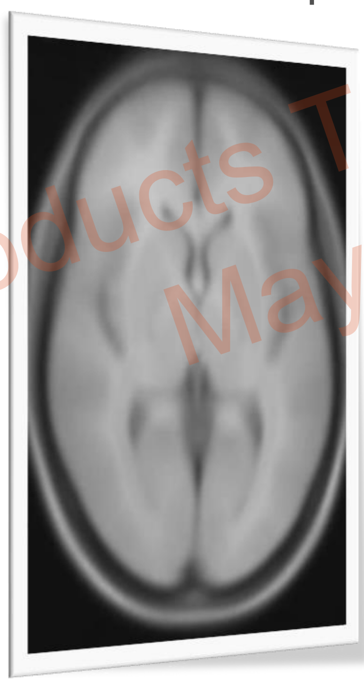
adapted from Acar ZA (2013) Effect of forward model errors on EEG source localization.

(4) Forward Problem: Co-registration

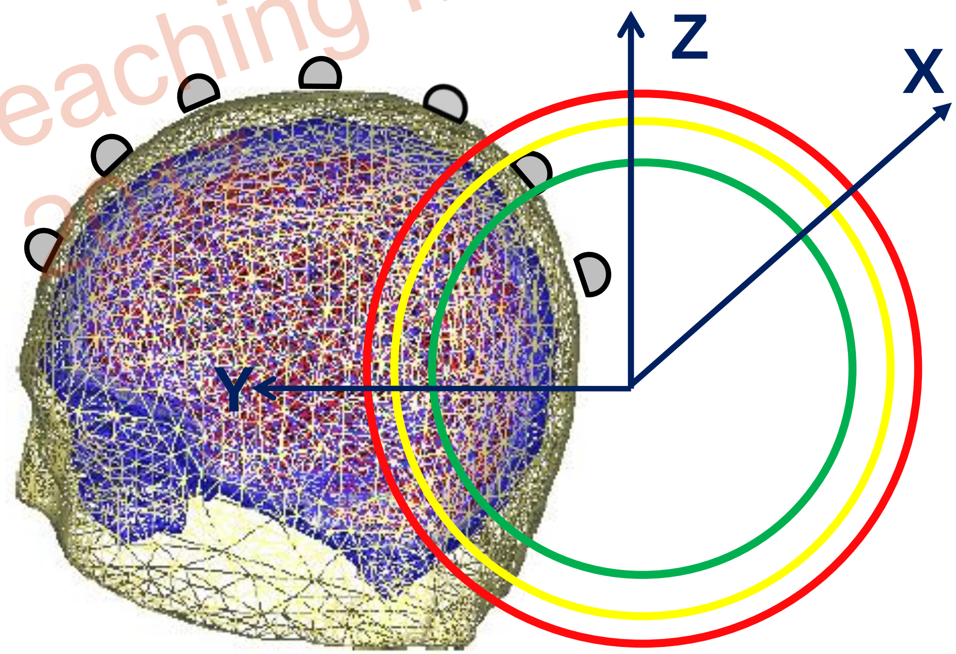
- To compute the electrical signals produced by dipole(s),
  - the anatomy,
  - the head model and
  - the electrode positions

  must be expressed in the same coordinate system.
- Often the pre-auricular and nasion points are used as anatomical landmarks.

Talairach Atlas

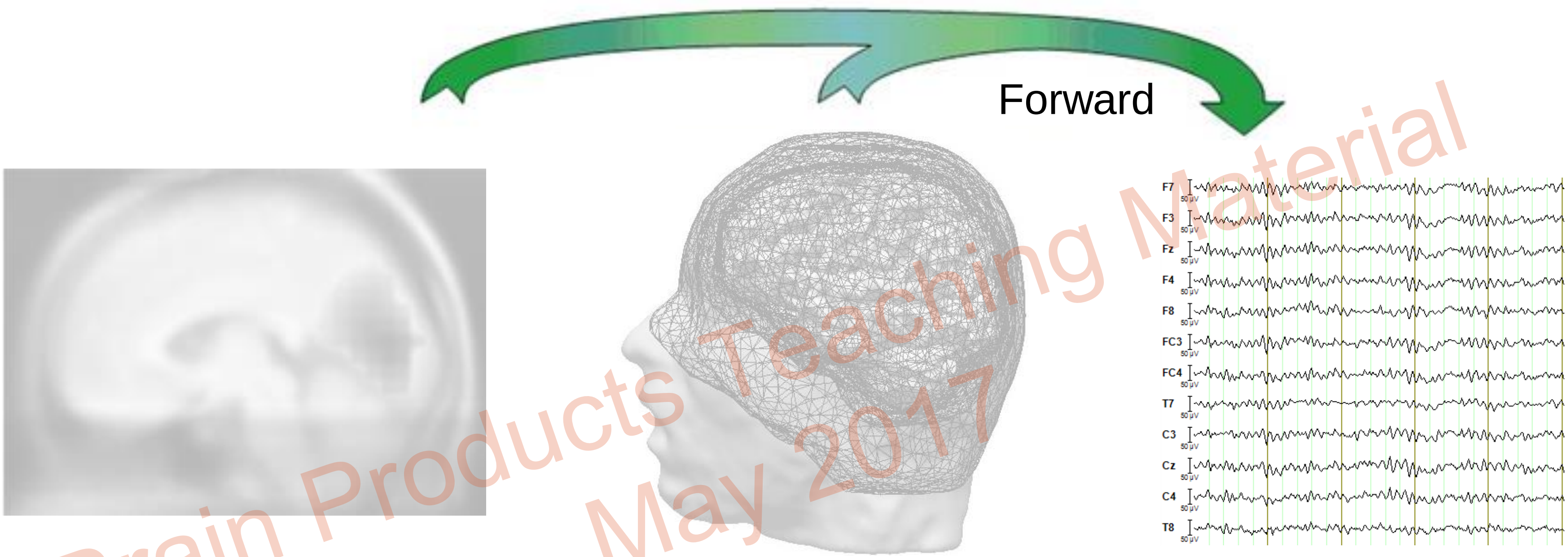


MNI Template



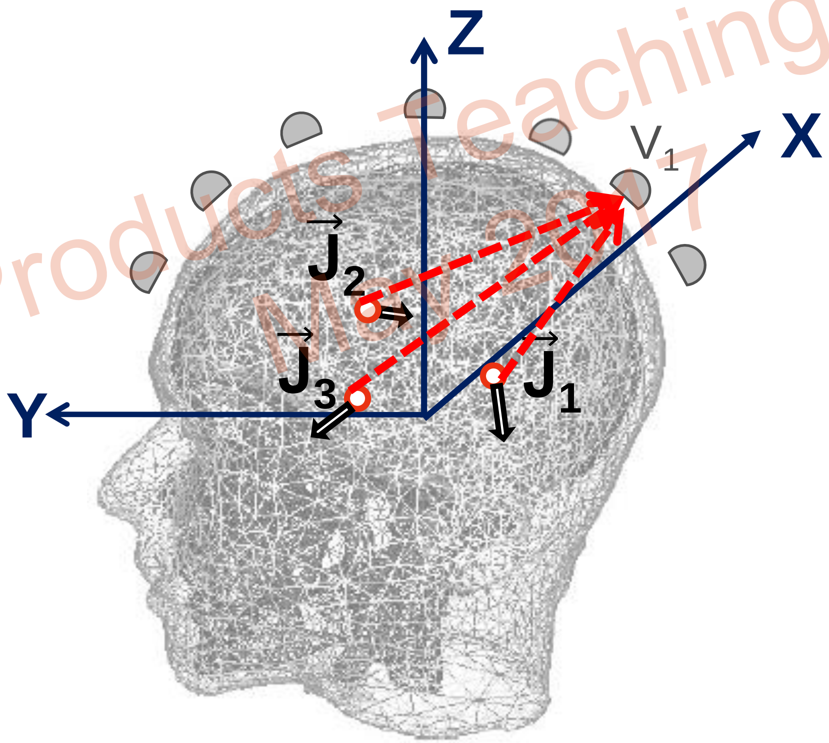
3-shell Spherical Model

Forward Solution



Forward Problem: Leadfield

- **Given**:
  - position, orientation, magnitude of any neuronal current sources ($\vec{J}$).
  - volume conductor geometry of the brain, skull, and scalp.
- **Wanted**: voltage distribution over the scalp (V).
  - **Leadfield** maps the neuronal current values to the voltage measurements at a specific position.



Forward Problem: Leadfield Matrix

- For **N** number of channels, the **leadfield matrix, G,** representing the solution to the forward problem given one single dipole or **M** multiple dipoles in the x-, y-, and z- directions is given as:

$$G_{(N \times 3)} = \begin{bmatrix} g_1 \\ g_2 \\ \vdots \\ g_N \end{bmatrix}$$

For single source

$$G_{(N \times 3M)} = \begin{bmatrix} g_{1,1} & g_{1,2} & \cdots & g_{1,M} \\ g_{2,1} & g_{2,2} & \cdots & g_{2,M} \\ & & \vdots & \\ g_{N,1} & g_{N,2} & \cdots & g_{N,M} \end{bmatrix}$$

For M sources

$$g_{(3 \times 1)} = \begin{bmatrix} g_x & g_y & g_z \end{bmatrix}$$

Forward Solution: from Dipoles to Scalp Topography

- Modeling of the potentials produced by the dipoles.
  - From Source (**J**) to Voltage (**V**): Poisson's equation

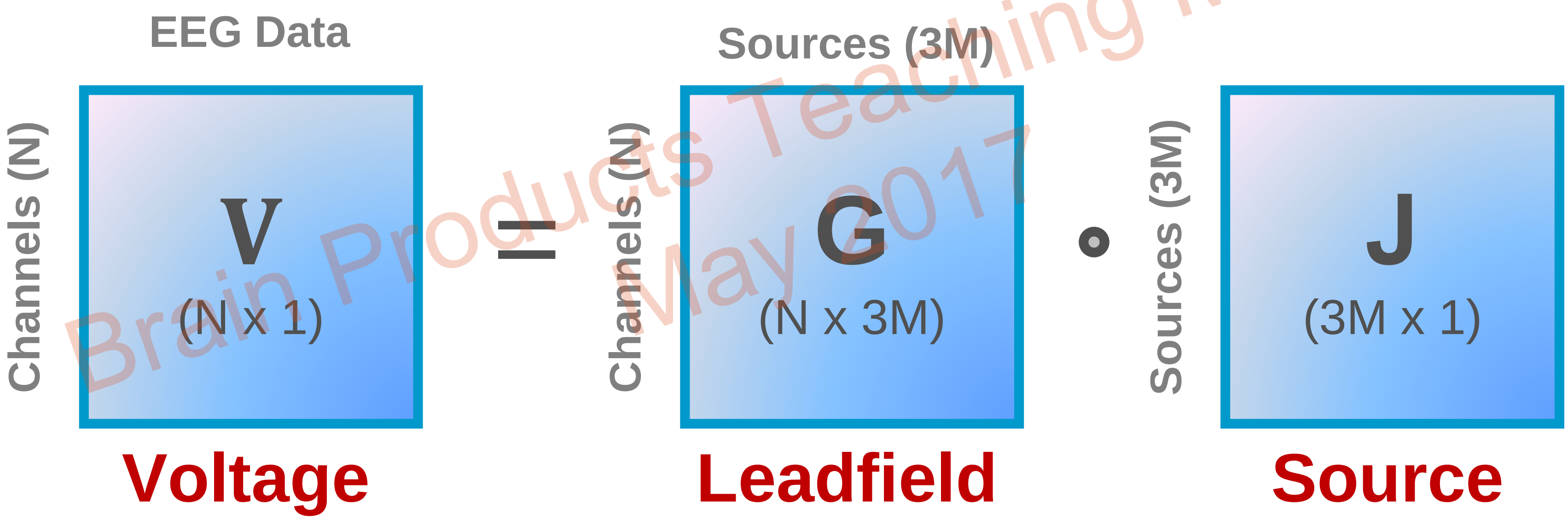
$$\nabla \cdot (\sigma \nabla V) = \nabla \cdot J$$

σ: conductivity

∇: derivative operator

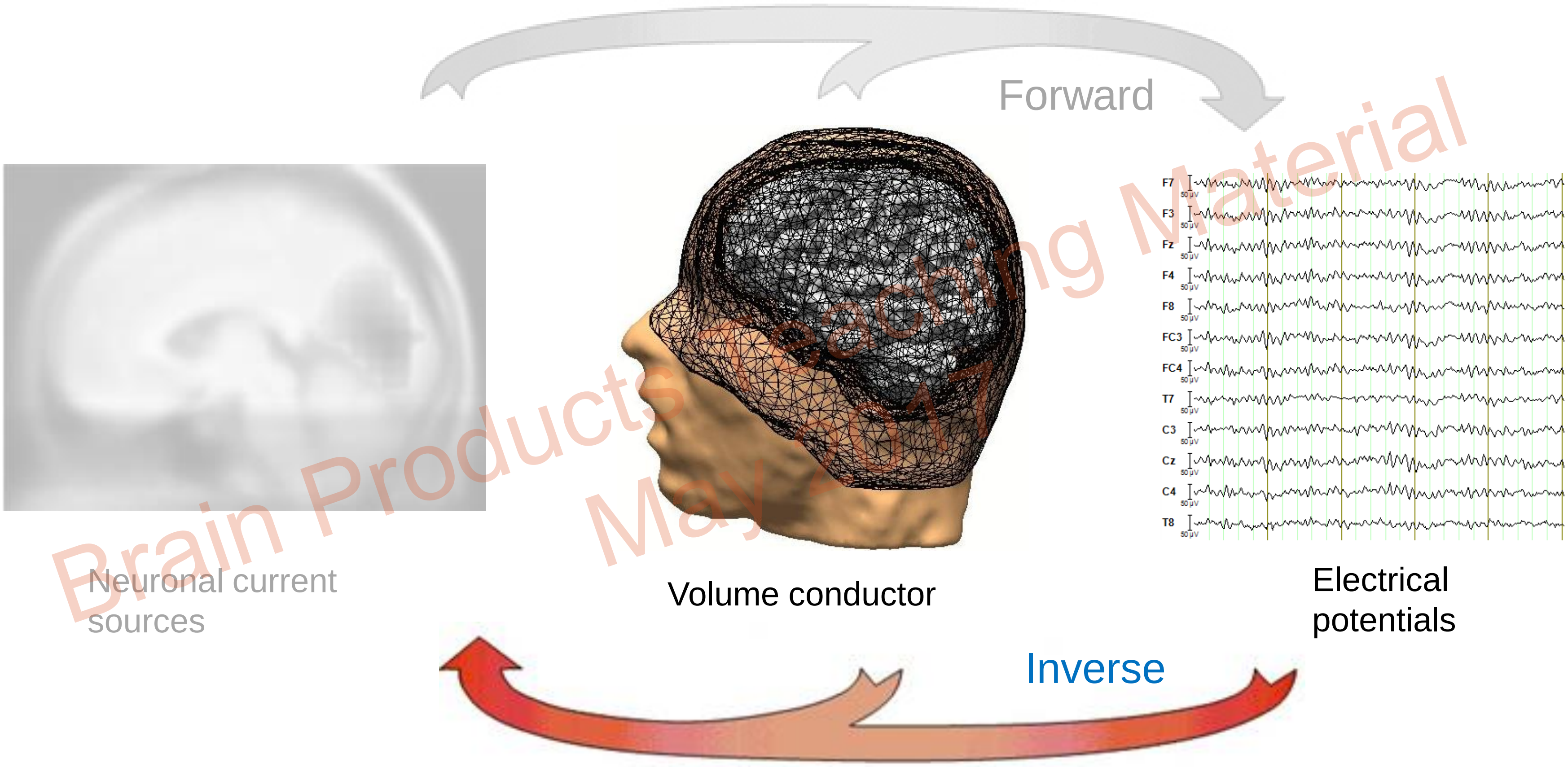
V: electric potential

J: current source density



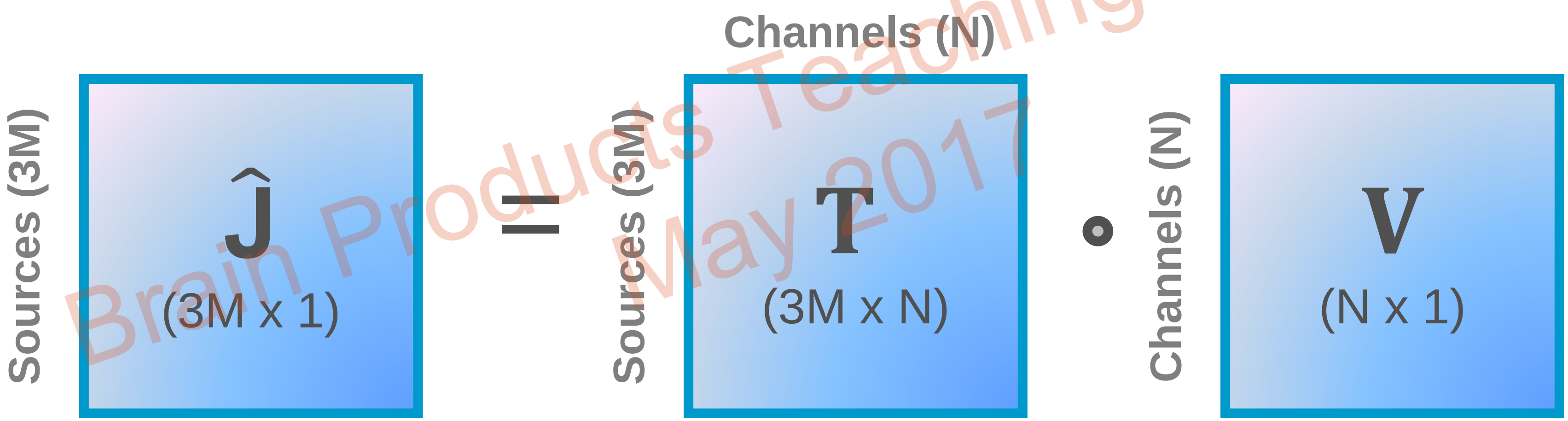
Interim Summary

- EEG signal is generated by neuronal current sources.
  - Current sources are distributed assemblies modeled using equivalent current dipoles located in source space.
- The relation between source matrix and voltage matrix is mediated by the Leadfield comprising:
  - the physics of how currents and electric fields behave inside the conductive medium (head).
  - a volume conduction model (providing geometric and resistive properties).
- Solving the forward problem enables us to determine the electrical potentials created by the primary current sources.
  - An accurate forward solution is a necessary pre-requisite for solving the inverse problem.


Forward
F7
F3
Fz
F4
F8
FC3
FC4
T7
C3
Cz
C4
T8
Neuronal current sources
Volume conductor
Electrical potentials
Inverse

Inverse Problem

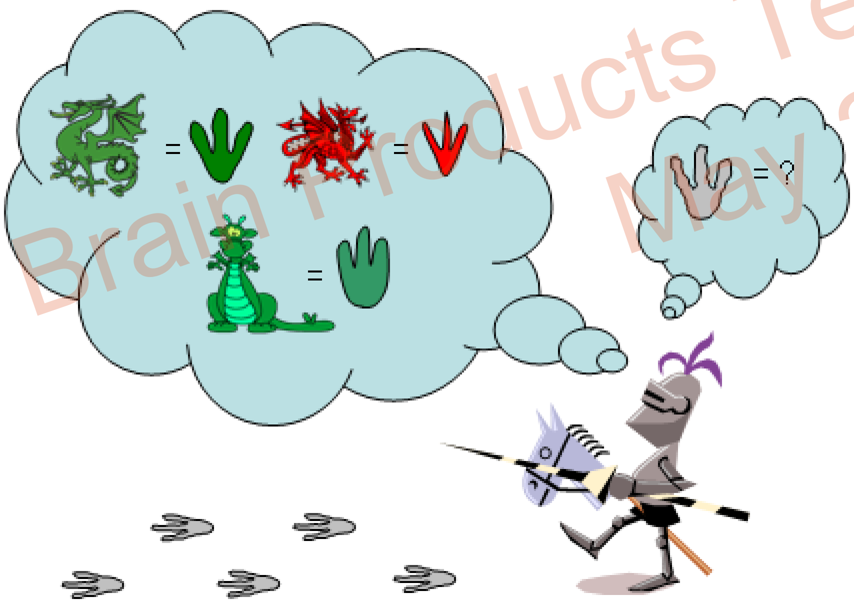
- **Given**: voltage measurements obtained from the forward problem.
- **Wanted**: equivalent source (current dipole) described by its:
  - position
  - orientation
  - magnitude



Source **Generalized inverse matrix** **Voltage**

Inverse Problem

- Estimation of the currents that produced the measured data → ill-posed problem!
- What is a well-posed problem? (as defined by the Mathematician Jacques Hadamard)
  - The problem must have a solution.
  - The solution must be unique.
  - The solution must be stable under small changes to the data.



- Different current distributions can explain the measured data → non-unique solutions (M>>N).
- Estimated sources can be sensitive to noise → unstable.

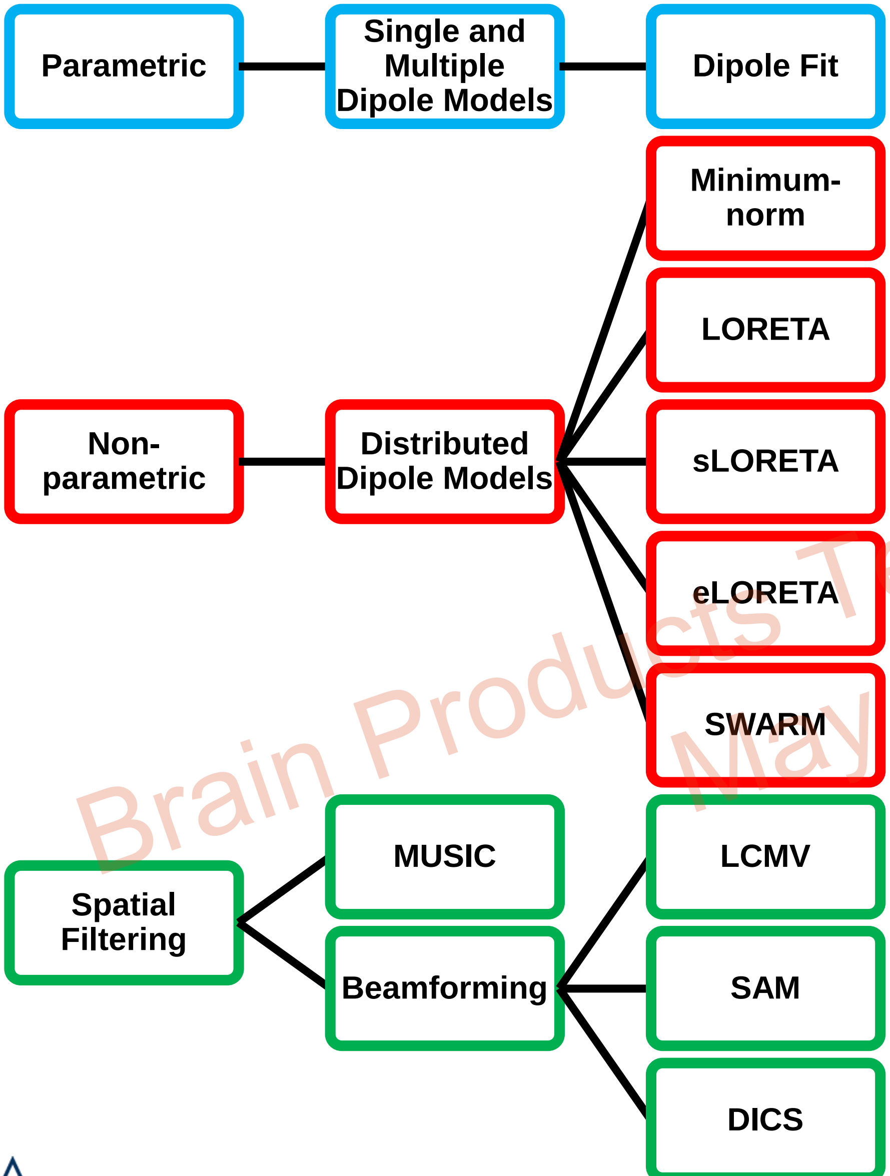
Inverse Problem

- How do we tackle the ill-posed nature of the inverse problem?
  - By setting certain assumptions/constraints.
    - Functional constraints:
      - *a priori* information about the number of sources/dipoles.
      - dipole location and/or orientation can be fixed which reduces the number of parameters.

Dipole Models	Number of parameters to be estimated
Moving	6 (free location (x, y, and z), free orientation (ɵ and ϕ), and magnitude)
Rotating	3 (free orientation (ɵ and ϕ) and magnitude)
Fixed	1 (magnitude of x-, y-, or z-components)

    - Mathematical constraints:
      - e.g., minimum-norm, maximum smoothness.
    - Anatomical constraints:
      - sources lie on a 3D cortical space (grid) and each grid consists of 3 dipole components i.e., in the x, y, and z-directions.

Inverse Methods



- ***a priori***: number of sources must be known.
- **Estimation**: location of the strongest source.

- ***a priori***: location of the source space.
- **Estimation**: distribution of activity (current density) over the entire brain (source space).

- ***a priori***: sources need to be temporally uncorrelated.
- **Estimation**: contribution of a source to the measured data at a specified location.

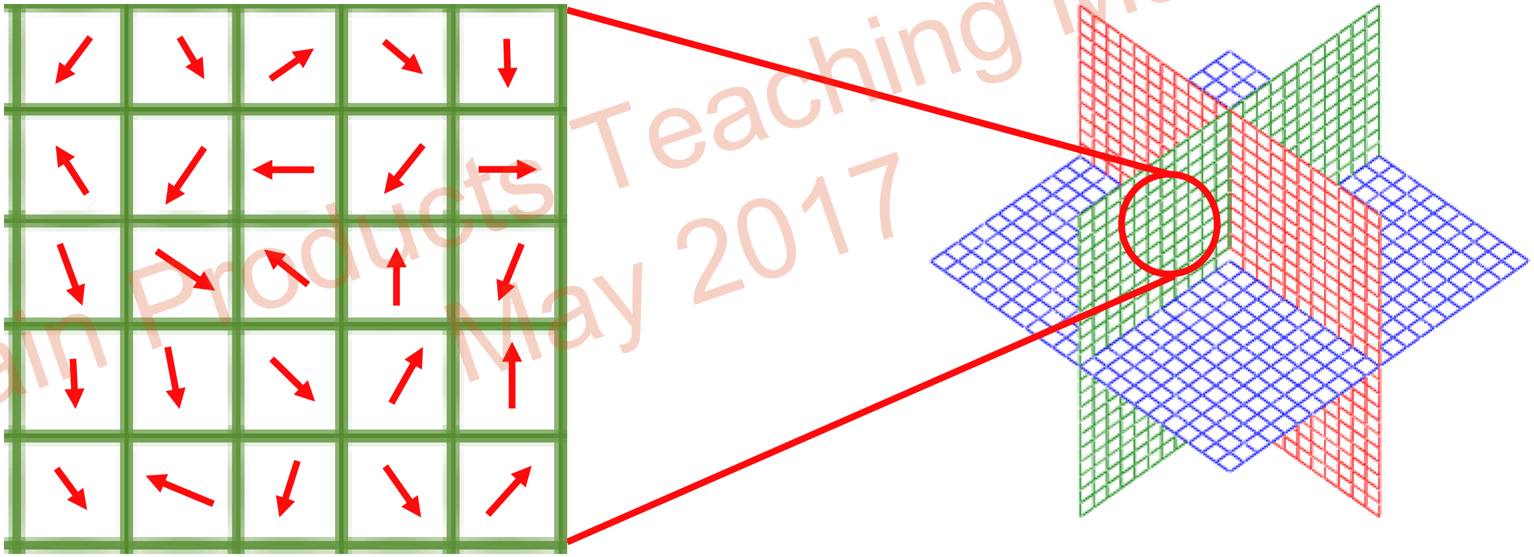
2

Theoretical basis of LORETA

Lo**w** **R**esolution Brain **E**lectromagnetic **T**omography

What is LORETA?

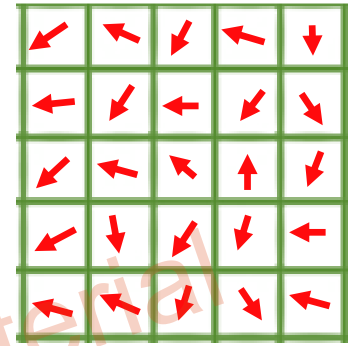
- LORETA is one of the most established distributed-source imaging or current density reconstruction methods.
  - The distributed activity throughout the brain volume is computed.
    - The volume is discretized as a dense 3D grid where a single dipole is located on each grid point confined in a given source space (e.g., the cortex).



- **Goal**: Estimate the magnitude of the dipole at each grid point (voxel).

Theoretical basis of LORETA

- **Assumption:** neighboring sources tend to be synchronized i.e., they have similar orientation and magnitudes.
- **Mathematical constraint**: maximal smoothness of source intensity values.
  - Introduce a source model term based on the Laplacian operator (second spatial derivative).
  - **Smoothest possible (unique) inverse solution!**
- LORETA's localization properties:
  - Low spatial resolution preserving the location of maximal activity.

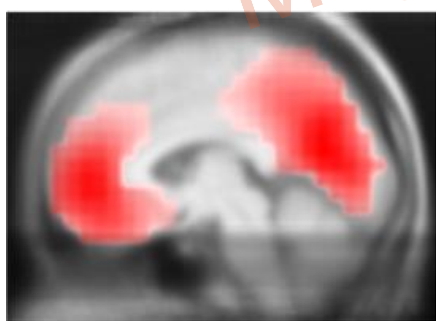


W: source-depth weighting matrix

λ: regularization parameter

B: Laplacian operator

2 distinct sources

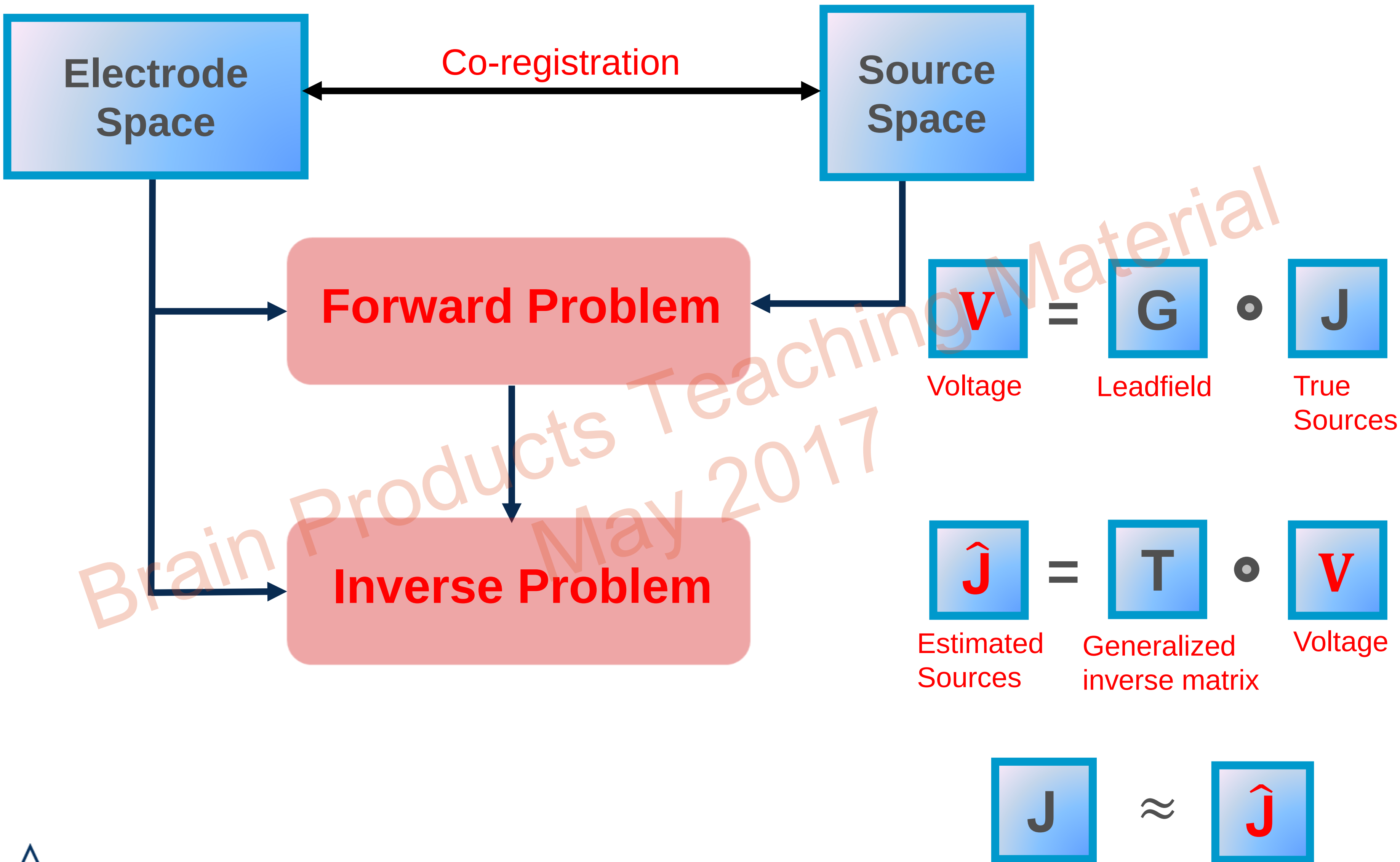


The corresponding smoothed activation map

$$\min_{\vec{J}} \underbrace{\|V - GJ\|_2}_{\text{Data term}} + \lambda \underbrace{\|BWJ\|_2}_{\text{Source term}}$$

$$\hat{J} = \underbrace{(WB^TBW)^{-1}G^T * \{G(WB^TBW)^{-1}G^T\}^+}_{T} \cdot V$$

$$\Rightarrow \quad \hat{J} = T \cdot V$$


Electrode Space
Co-registration
Source Space
Forward Problem
Inverse Problem
V = G • J
Voltage
Leadfield
True Sources
Ĵ = T • V
Estimated Sources
Generalized inverse matrix
Voltage
J ≈ Ĵ

Brain Products
Solutions for neurophysiological research

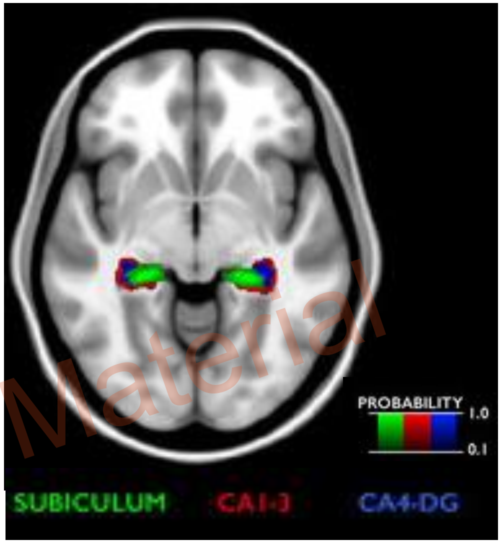
3

Implementation of LORETA in Analyzer 2

BrainVision professional Analyzer 2

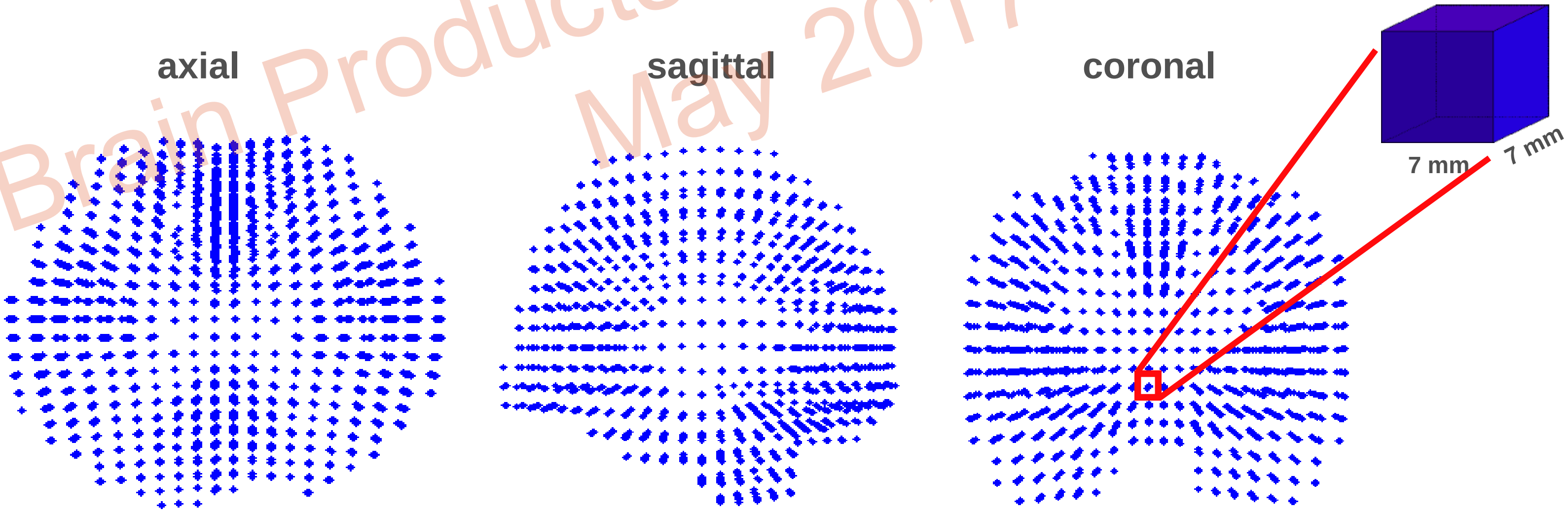
LORETA Ingredients: Source Model

- Solution space is restricted to cortical gray matter and hippocampus in the Talairach atlas (brain areas corresponding to the digitized Probability Atlas of the MNI).

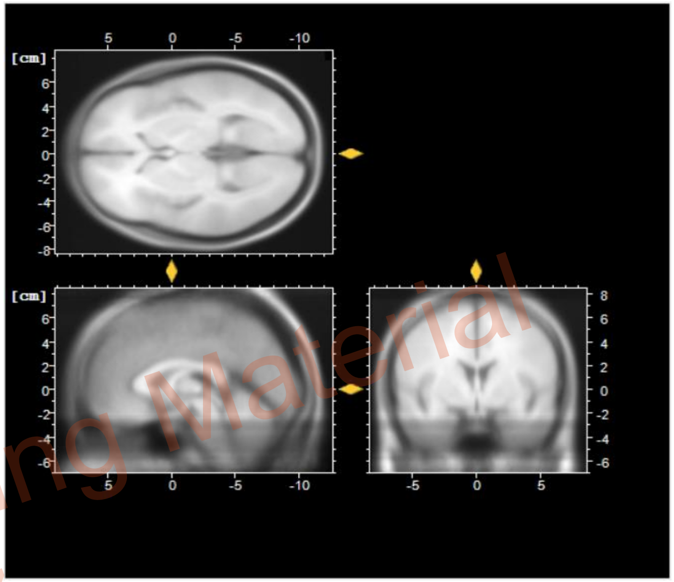


adapted from Kulaga-Y.J. et al. (2015) Multi-contrast submillimetric 3 Tesla hippocampal subfield segmentation protocol and dataset.

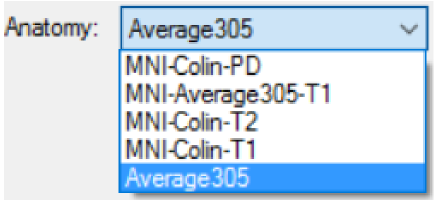
- The source space grid comprises 2394 voxels at 7 mm spatial resolution.



LORETA Ingredients: Anatomical and Head Model



- Anatomies
  - Based on MNI templates:
    - **MNI-305** (Collins, 1994):
      - average of the 3D brain T1 weighted MR images of 305 representative subjects.
    - **MNI-Colin** (scans of MNI lab member Colin Holmes):
      - Colin-PD weighted images.
      - Colin-T2 weighted images.
      - Colin-T1 weighted images.

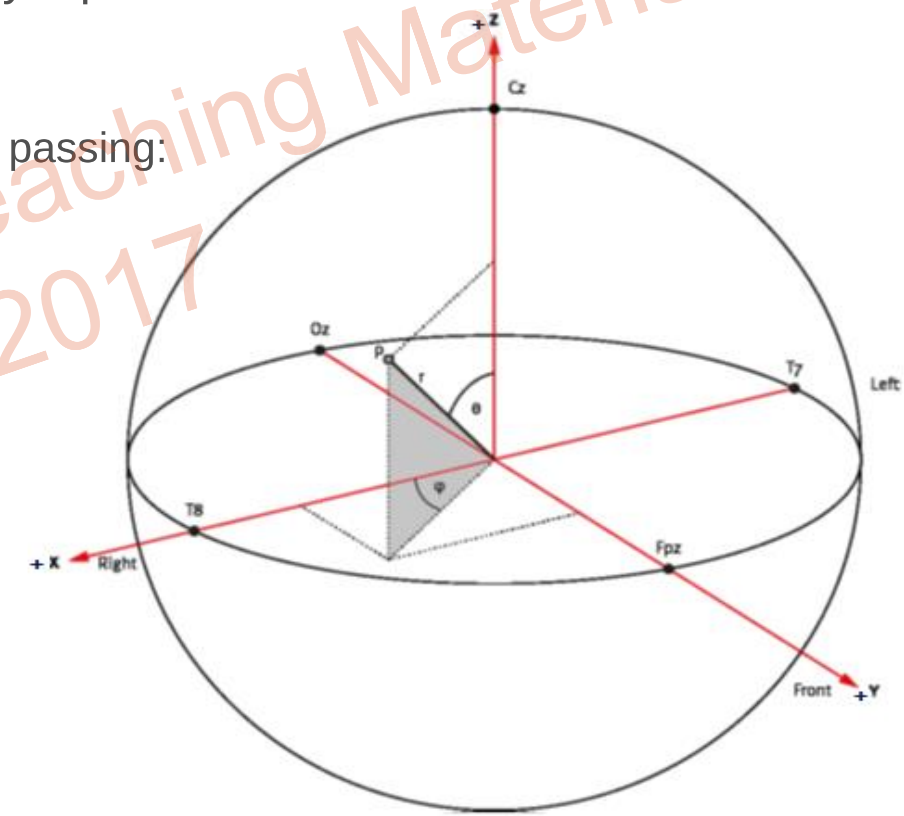


  - Co-registered to Talairach atlas (Talairach & Tournoux, 1988).
    - Brain structures (defined in the Talairach atlas).
- Head Model
  - 3-shell spherical head model registered to the Talairach human brain atlas based on the MNI brain.

LORETA Ingredients: Co-registration

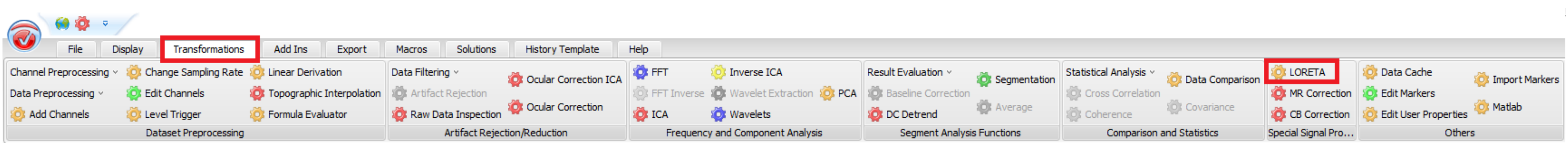
- Expressing electrode co-ordinates and the head anatomy in the same coordinate system.

- Spherical coordinates are used to specify a point on the surface of the head.
  - Consisting of the variables r, θ, φ.
  - The origin is the intersection of the lines passing:
    - through **T7** and **T8** (x-axis).
    - through **Oz** and **Fpz** (y-axis).
    - through **Cz** (z-axis).
  - Radius for:
    - non-scalp electrodes (e.g., ECG), **r = 0**.
    - scalp electrodes, **r = 1**.

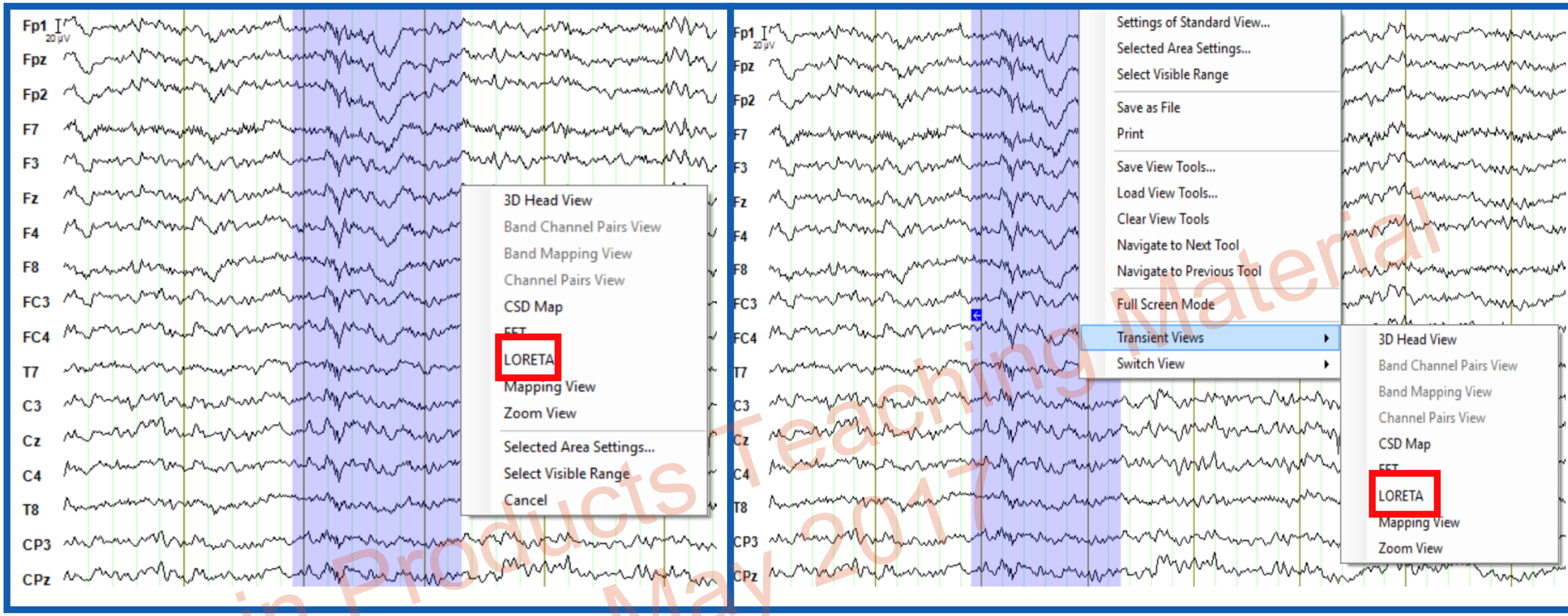


Usability of LORETA in Analyzer 2

- LORETA transformation is accessible as a:
  - Transient transformation
    - For temporary display and inspection of the EEG data.
      - Exploratory analysis which provides a first impression about the location of areas of activation (clusters) → to infer the Region-of-Interests (ROIs).
    - Computation is done only for data points selected by the user.
    - Output is generated in a dockable window in the main window display.
  - Primary transformation
    - Allows to specify ROIs.
    - Generates a new history node which contains the average current density within each ROI (provided as a LORETA channel).



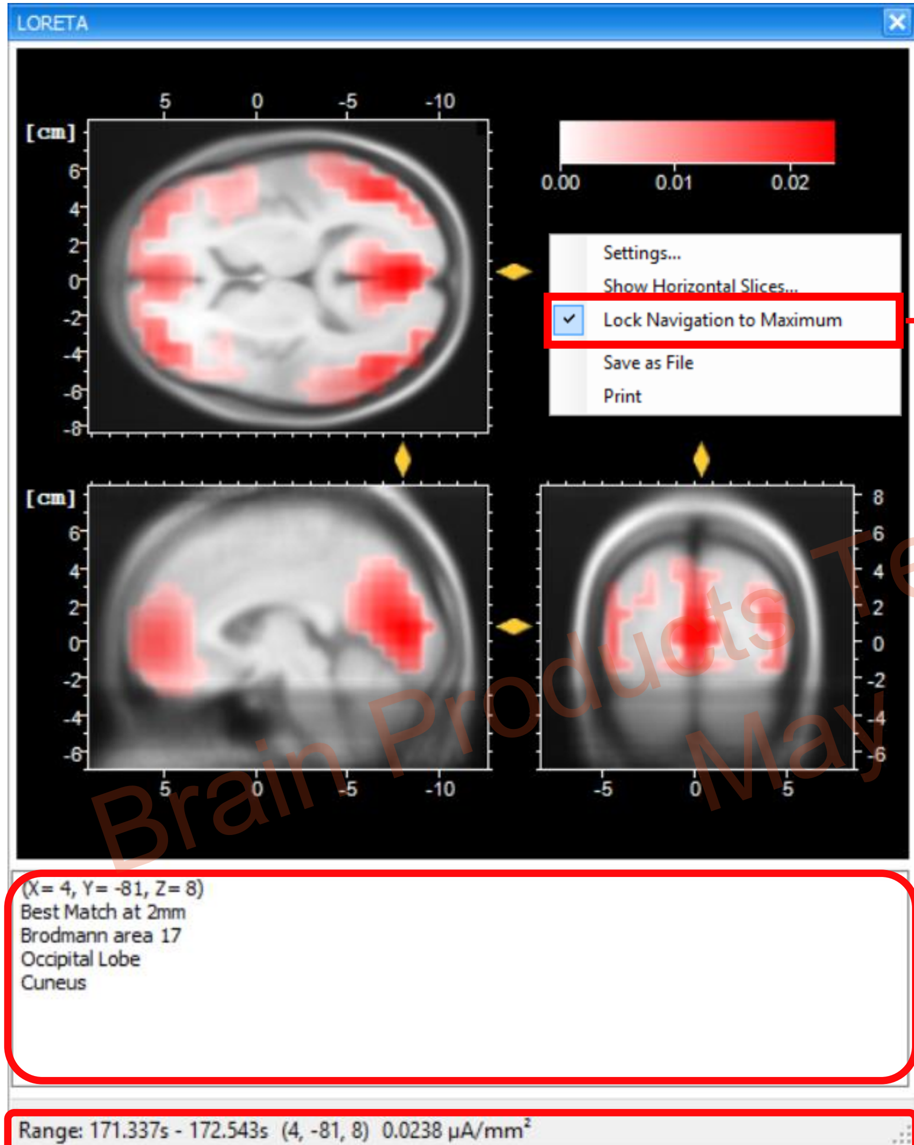
LORETA: as a Transient Transformation



- Option 1
  - Use the mouse to select an interval.
  - Release the mouse button.
  - Contex menu appears in which you can select LORETA.

- Option 2
  - An interval has already been selected.
  - Right-click to access the contex menu.
  - Click on Transient Views to acess the visualization options and select LORETA.

LORETA: as a Transient Transformation

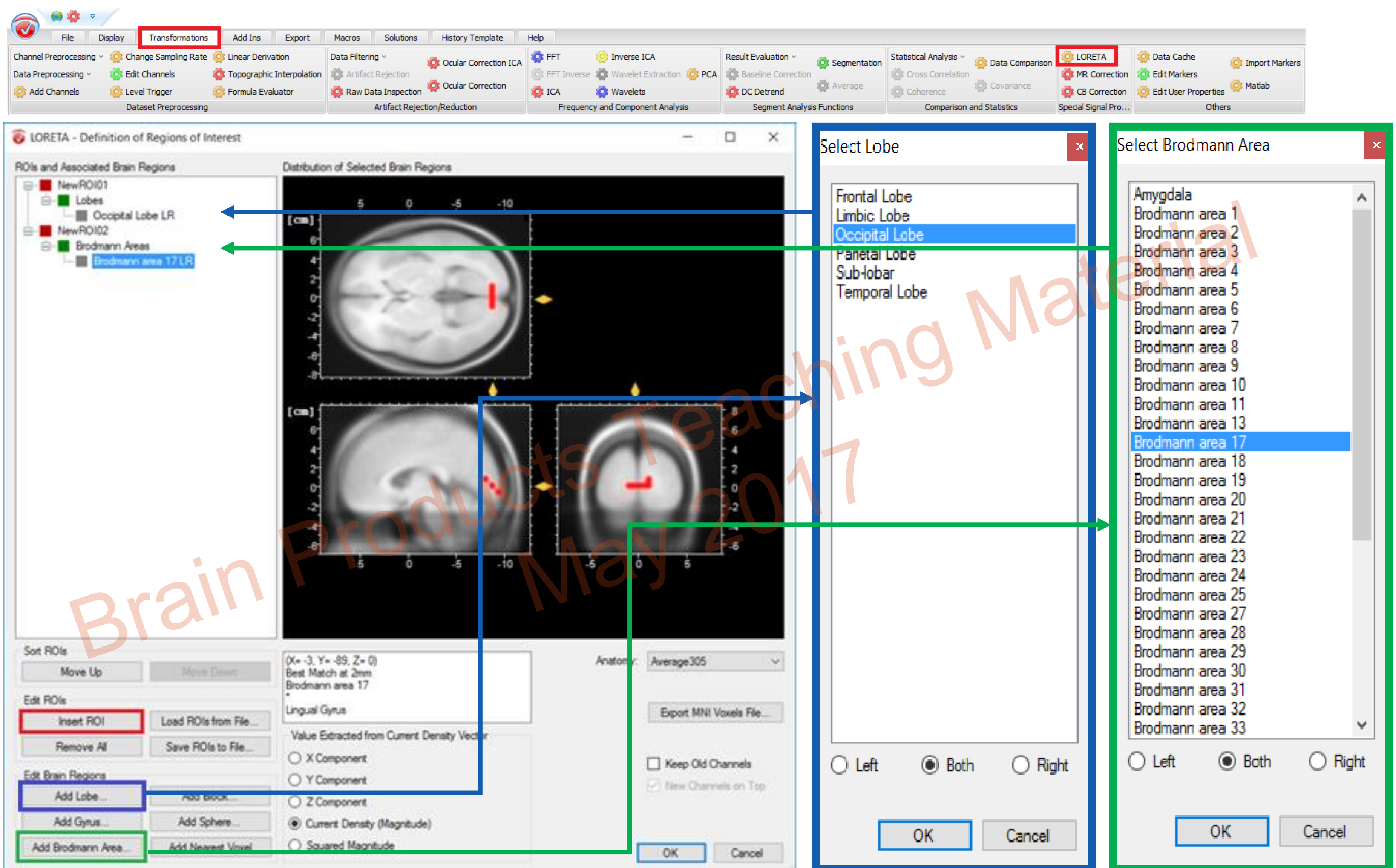


- Right-click to access the context menu.
- If Lock Navigation to Maximum is checked, the maximum current density will be displayed at the status bar of the LORETA window and the crosshair will be set to its position.

- Coordinates of the current position of the mouse pointer (crosshair).
- Anatomical brain areas in the vicinity of the mouse pointer.

- Range: time-interval selected by the user.
- Coordinates of the voxel under the current position of the mouse pointer (crosshair).
- Current density (magnitude) = mean of all current density vectors within the range associated to that specific voxel.

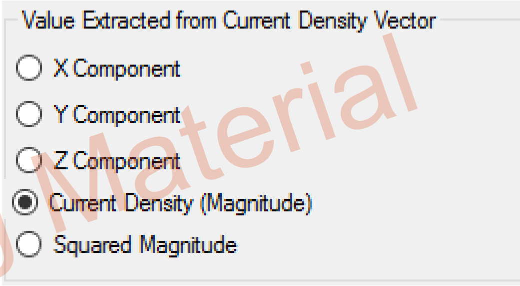
LORETA: as a Primary Transformation



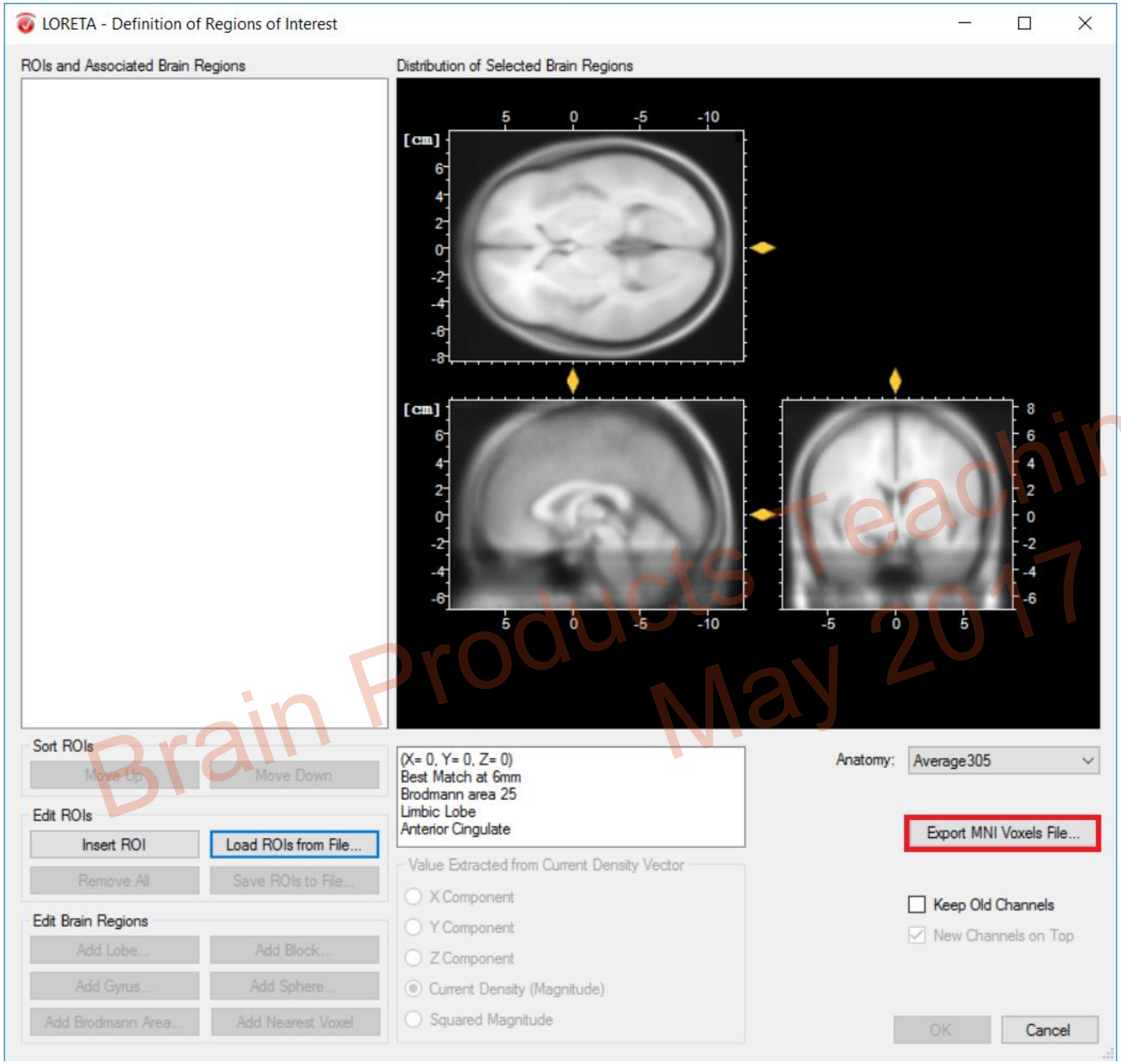
Outputs of LORETA

- LORETA computations can be specified for:
  - mean of the current density vectors across the:
    - X Component
    - Y Component
    - Z Component

    within a ROI.
  - mean of all current density vectors within a ROI.
    - Current Density (Magnitude)
  - power of the mean current density vectors within a ROI.
    - Squared Magnitude



Loading ROIs



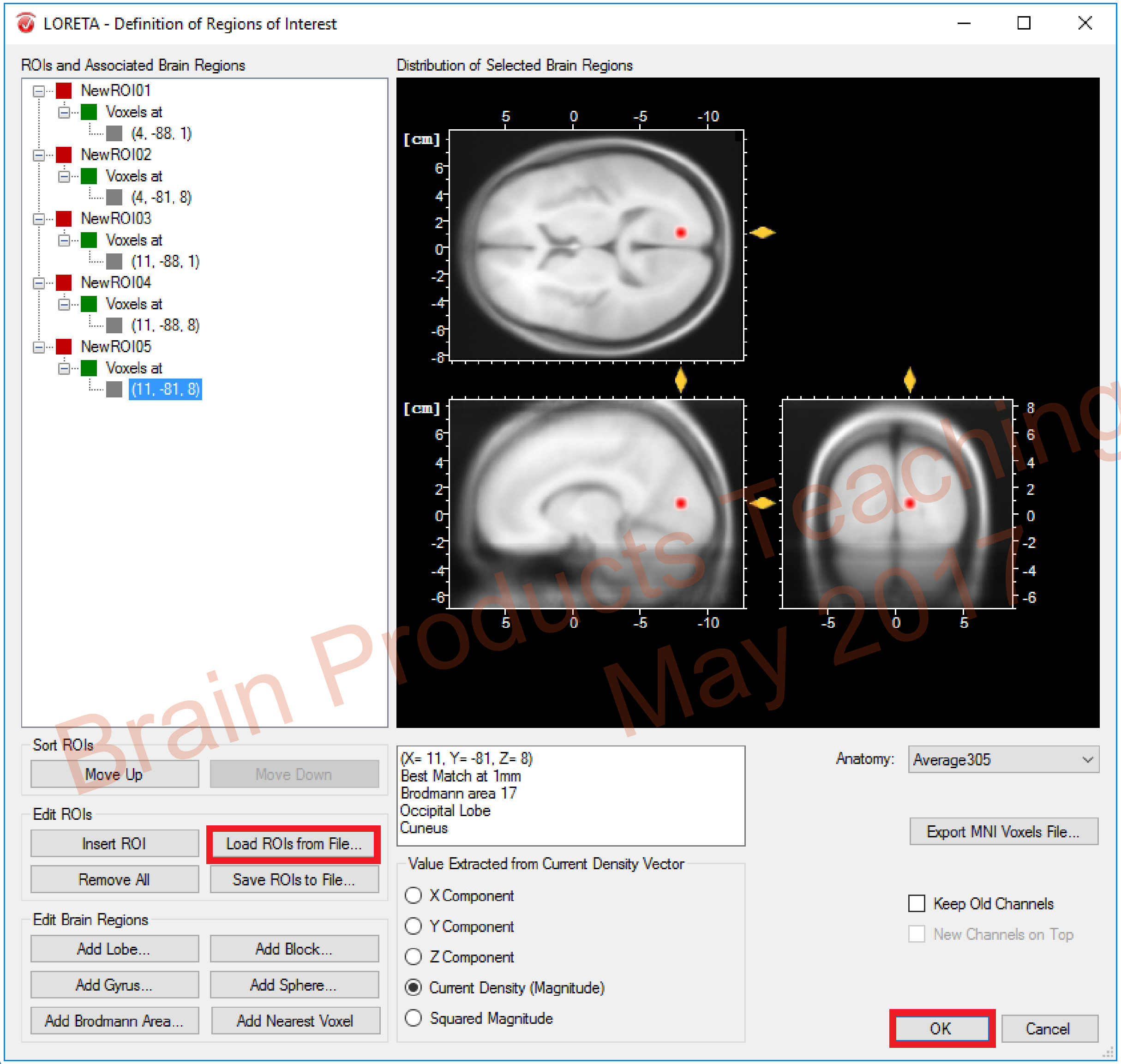
- Export the predefined ROI template to a *.csv file using the option "Export MNI Voxels File..."
- The *.csv file contains the x-, y-, and z- MNI coordinates as well as the associated anatomical data of the brain areas consisting of 2394 voxels in the source space.

Loading ROIs

A	B	C	D	E	F	G
2394 = number of voxels						
5 = number of ROIs						
X-MNI	Y-MNI	Z-MNI	Lobe	Structure	Brodmann area	ROI-number [1...0] (if zero then not included in any ROI)
-52	-11	-41	Temporal Lobe	Inferior Temporal Gyrus	Brodmann area 20	0
-45	-11	-41	Temporal Lobe	Inferior Temporal Gyrus	Brodmann area 20	0
-38	-11	-41	Limbic Lobe	Uncus	Brodmann area 20	0
-31	-11	-41	Limbic Lobe	Uncus	Brodmann area 20	0
32	-11	-41	Limbic Lobe	Uncus	Brodmann area 20	0
39	-11	-41	Temporal Lobe	Inferior Temporal Gyrus	Brodmann area 20	0
-31	-88	1	*	Middle Occipital Gyrus	Brodmann area 18	0
-10	-88	1	*	Lingual Gyrus	Brodmann area 17	0
-3	-88	1	*	Lingual Gyrus	Brodmann area 17	0
4	-88	1	*	Lingual Gyrus	Brodmann area 17	1
11	-88	1	*	Lingual Gyrus	Brodmann area 17	2
32	-88	1	*	Middle Occipital Gyrus	Brodmann area 18	0
39	-88	1	*	Middle Occipital Gyrus	Brodmann area 18	0
-31	-88	8	Occipital Lobe	Middle Occipital Gyrus	Brodmann area 19	0
-3	-88	8	Occipital Lobe	Cuneus	Brodmann area 18	0
4	-88	8	Occipital Lobe	Cuneus	Brodmann area 18	0
11	-88	8	Occipital Lobe	Cuneus	Brodmann area 17	3
32	-88	8	Occipital Lobe	Middle Occipital Gyrus	Brodmann area 19	0
39	-88	8	Occipital Lobe	Middle Occipital Gyrus	Brodmann area 18	0
-45	-81	8	Occipital Lobe	Middle Occipital Gyrus	Brodmann area 19	0
-10	-81	8	Occipital Lobe	Cuneus	Brodmann area 17	0
-3	-81	8	Occipital Lobe	Cuneus	Brodmann area 17	0
4	-81	8	Occipital Lobe	Cuneus	Brodmann area 17	4
11	-81	8	Occipital Lobe	Cuneus	Brodmann area 17	5
39	-81	8	Occipital Lobe	Middle Occipital Gyrus	Brodmann area 19	0
46	-81	8	Occipital Lobe	Middle Occipital Gyrus	Brodmann area 19	0
-52	-74	8	Temporal Lobe	Middle Temporal Gyrus	Brodmann area 39	0
-45	-74	8	Temporal Lobe	Middle Temporal Gyrus	Brodmann area 39	0

- Open the file in Excel/notepad and search for the desired ROI and number the identified voxels by changing the ROI-number (as shown in column G) from 0 to 1, 2, 3, 4,....
- Save the *.csv file containing all the 2394 voxels after marking the desired voxels within a ROI.

Loading ROIs



- Load the modified *.csv file using the button "Load ROIs from File..."
- After pressing OK a node named LORETA will be generated in the history tree containing the source signals corresponding to the desired voxels within a ROI.

Requirements and Recommendations

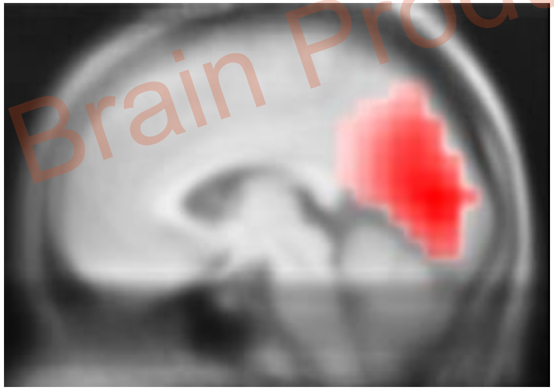
- Pre-requisites of source analysis (LORETA):
  - spatial arrangement of the scalp electrodes (electrode positions: standard or realistic).
  - time-domain EEG data.

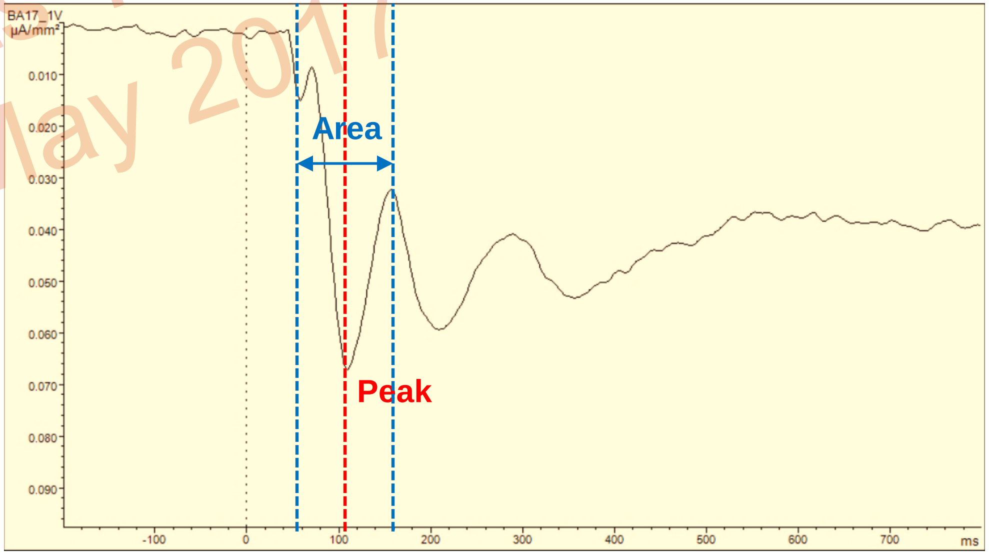
- Recommended conditions for the quality of source analysis:
  - number of electrodes >= 64.
  - uniform distribution of electrodes across the head → Equidistant electrode positioning.
  - low electrode positioning error → use high-precision electrode localizer, for e.g., CapTrak.
  - high signal-to-noise ratio (SNR) of input data → good data pre-processing.

Interim Summary

- Modes of LORETA operation in Analyzer 2:
  - as a Transient transformation.
    - For temporary display and inspection purpose.
    - Computation is done only for data points selected by the user.
    - Outputs the average current density (magnitude) within the range associated to a specific voxel.
  - as a Primary transformation.
    - Allows defining and/or loading region of interest (ROIs) from a file.
    - Outputs for a single time point the:
      - current density (magnitude) for each specified component (x-,y-,z-) or,
      - average current density (magnitude) for the selected ROI or
      - power of the average current density for the selected ROI.

- Measure extraction and export for statistical analysis.
  - Export Current Density from LORETA.
    - Generic Data Export (via *Export > Node Export > Generic Data*).
    - Area Information Export (*via Export > Multiple Export > Area Information*).
  - Peak Detection (*via Transformations > Segment Analysis Functions > Result Evaluation > Peak Detection*).
    - Peak Information Export (*via Export > Multiple Export > Peak Information*).





Limitations of LORETA

- LORETA has a low spatial resolution and assumes that neighboring sources are correlated.
  - However, functionally very distinct areas can be anatomically very close. Therefore, the argument of correlation as a physiological justification for the LORETA algorithm should be taken with caution.
  - Moreover, far-distance correlations result in over-smoothed, blurred solutions. For instance, homologous areas in both hemispheres or two distinct areas along a sulcus.
- Frequency-domain and time-frequency domain source analyses are not supported (in Analyzer)!

Dos and DON'Ts of LORETA in Analyzer 2

- The **only** valid input to LORETA is voltage (time-domain).

- LORETA transform **shall not** be applied to:

  - CSD
  - FFT and Coherence spectra
  - Wavelets
  - Complex Demodulation
  - Z-transformed data
  - P-values
  - T-test values
  - Bipolar recordings

more details: http://www.uzh.ch/keyinst/NewLORETA/Misuse/Misuse.htm

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4

Open Questions Session

BRAINVISION
professional ANALYZER 2

5

Concluding Remarks

Take home messages

- Spatiotemporal EEG dynamics partially encode the information about the underlying neural dynamics.
- LORETA leads to reasonable source configurations but has its own limitations.
- Be aware of the requisites and misuses of the LORETA transform.
- ROIs for LORETA analysis should be defined at best on the basis of previous scientific reports.
- Exploratory analysis using LORETA Transient View can help you to identify areas of activation, which then can be potentially used as ROIs.
- Source analysis is great, is needed, but is a difficult problem. There is no “gold standard” method available yet. Be cautious in drawing inferences related to the location and magnitude of the sources.

References – Journal articles

- Pascual-Marqui RD, Michel CM, Lehmann D (1994). Low resolution electromagnetic tomography: a new method for localizing electrical activity in the brain. *International Journal of Psychophysiology*, 18:49-65.

- Pascual-Marqui RD, Lehmann D, Koenig T, Kochi K, Merlo MCG, et al. (1999). Low resolution brain electromagnetic tomography (LORETA) functional imaging in acute, neuroleptic-naive, first-episode, productive schizophrenia. *Psychiatry Res.,* 90: 169–179.

- Pascual-Marqui, RD (1999). Review of methods for solving the EEG inverse problem. *International Journal of Bioelectromagnetism, 1*(1), 75-86.

- Pascual-Marqui RD, Esslen M, Kochi K, Lehmann D (2002). Functional imaging with low resolution brain electromagnetic tomography (LORETA): a review. *Methods & Findings in Experimental & Clinical Pharmacology*, 24C:91-95.

- Michel CM, Murray MM, Lantz G, Gonzalez S, Spinelli L, et al. (2004). EEG source imaging. *Clinical Neurophysiology, 115*(10), 2195-2222.

References – Brain Products materials

- Analyzer User Manual (current version 2.1.1)
  - http://www.brainproducts.com/downloads.php?kid=5&tab=2#dlukat_52

7.6 Transforms in the Special Signal Processing group

7.6.1 LORETA

Source analysis aims at solvin[…] current sources in the brain fr[…]

8.5 LORETA

The transient LORETA transform is used for source localization based on the Low Resolution Electromagnetic Tomography procedure described by R. D. Pascual-Marqui.

- Brain Products Press Release
  - http://www.brainproducts.com/downloads.php?kid=21&tab=1

Beyond surface EEG: An invitation to source analysis with LORETA

Brain Products / October 9, 2014

by Jose Raul Naranjo
Scientific Consultant (Brain Products)

This article presents the improved version of the LORETA transform in the new version of Analyzer 2.1.0 (to be released in the course of October 2014). The main features of the new LORETA dialog are explained and the virtues of LORETA analysis of EEG data are discussed. Hopefully this brief introduction will encourage you to use the new LORETA transform and push your research questions beyond the head surface into the neural source domain.

Introduction

The fundamental discovery of the human electroencephalogram (EEG) by Hans Berger gave a new twist to the history of human neuroscience. After many decades of research and applications, EEG continues to be a very active and stimulating field of research. One of the main reasons is that EEG reflects the underlying dynamic symphony of neural activity at the millisecond scale, which offers a privileged window into brain function and the neural underpinnings of cognition. However, non-invasive human EEG recordings meet a natural frontier at the head surface, which prohibits direct access to the neural source domain. Therefore, true neural activity can only be inferred from the electrical potentials measured at each electrode site on the scalp. Source analysis techniques aim to estimate the location and dynamics of the underlying neural generators of EEG, i.e., to provide a solution to the EEG inverse problem (Grech et al., 2008). Although there is theoretically no unique

If you have questions about this topic please contact us:
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