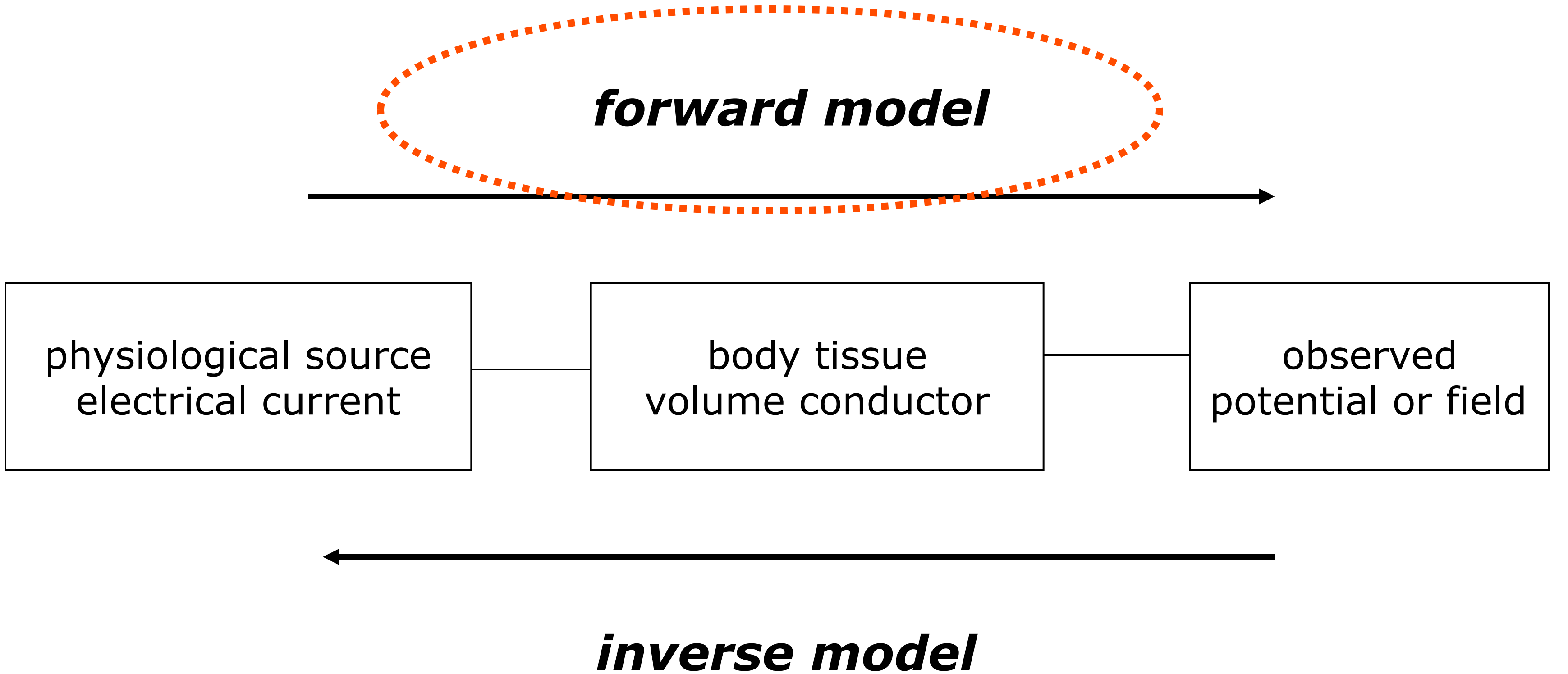
Forward and Inverse Modeling of EEG and MEG data

Robert Oostenveld

Donders Institute, Radboud University, Nijmegen, NL
NatMEG, Karolinska Institute, Stockholm, SE

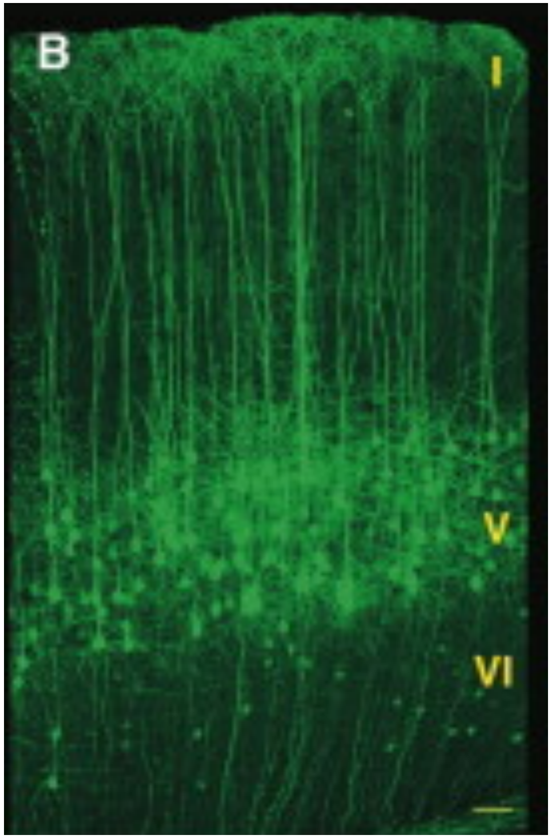
Biophysical source modelling: overview

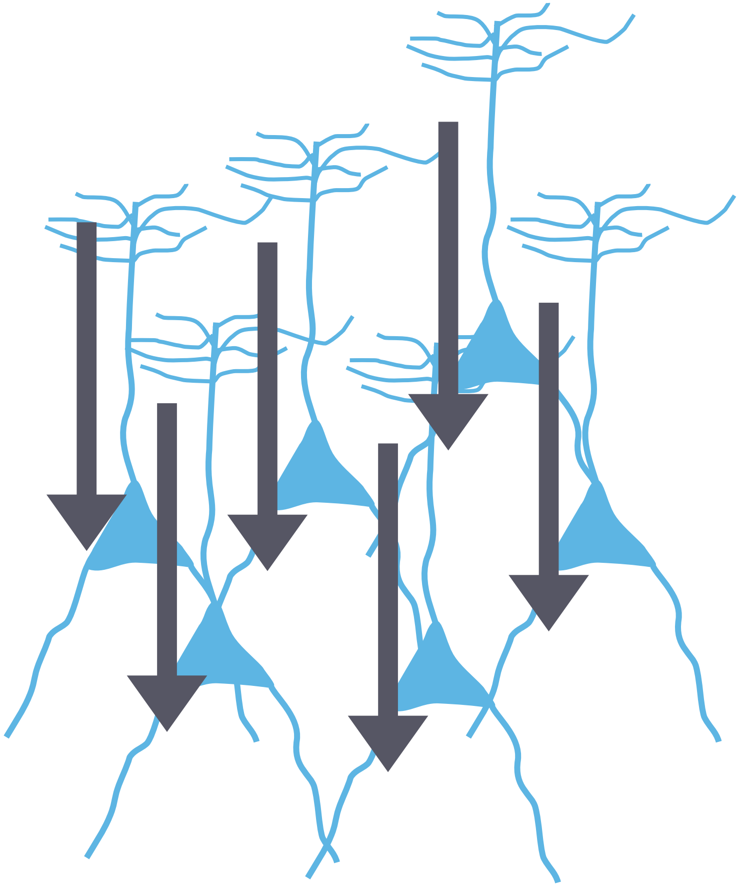


Overview

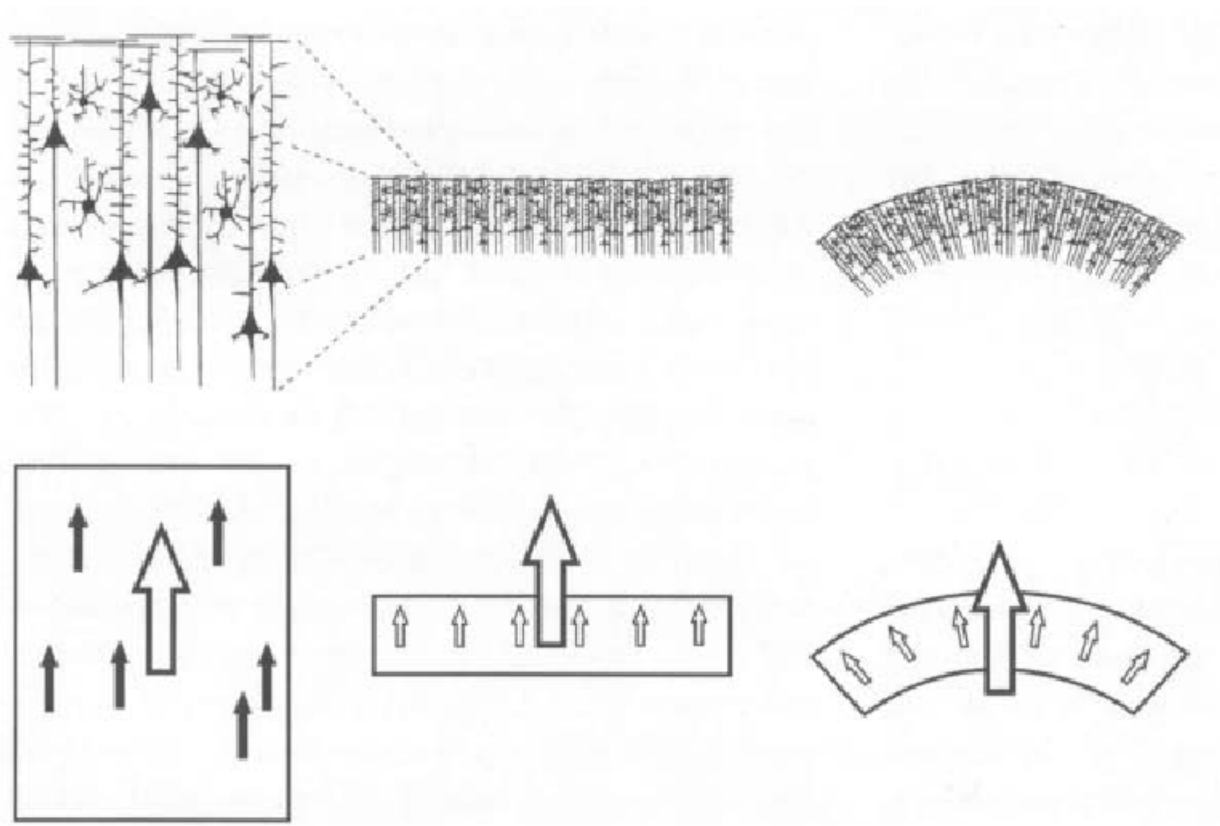
- Motivation and background
- **Forward modeling**
  - Source model
  - Volume conductor model
- Inverse modeling

What produces the electric current





Equivalent current dipoles



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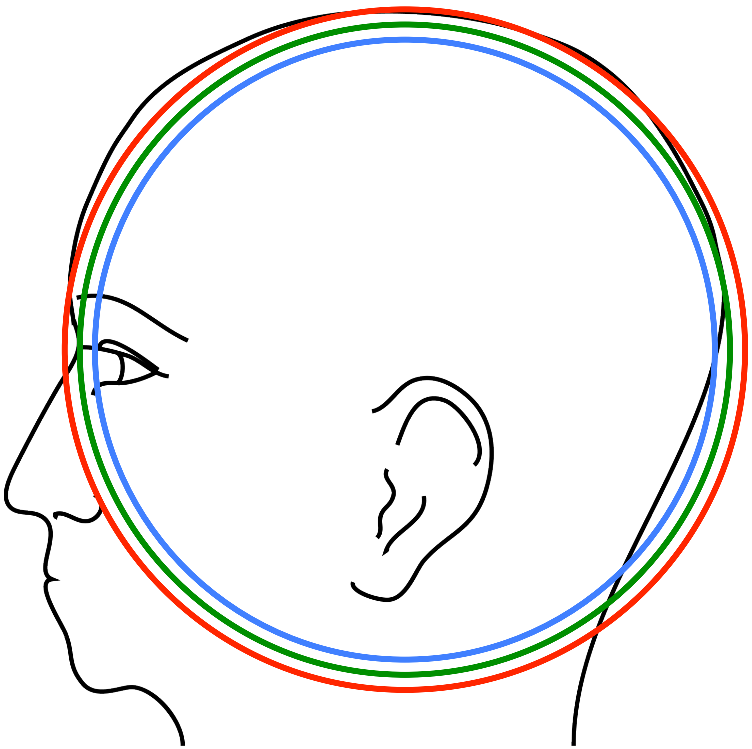
Volume conductor

described electrical
properties of tissue

describes geometrical
model of the head

describes **how** the currents
flow, not where they
originate from

same volume conductor for
EEG as for MEG, but also
for tDCS, tACS, TMS, ...



Volume conductor

Computational methods for volume conduction problem that allow for realistic geometries

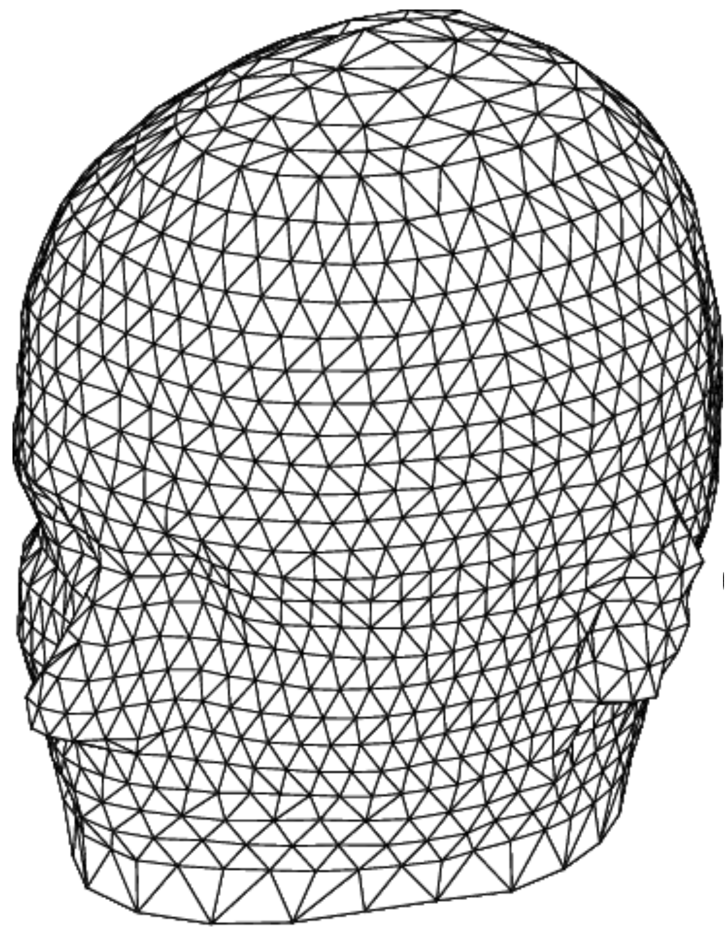
BEM	*Boundary Element Method*
FEM	*Finite Element Method*
FDM	*Finite Difference Method*

Volume conductor: Boundary Element Method

Each compartment is
- homogenous
- isotropic

Important tissues
- skin
- skull
- brain
- (CSF)

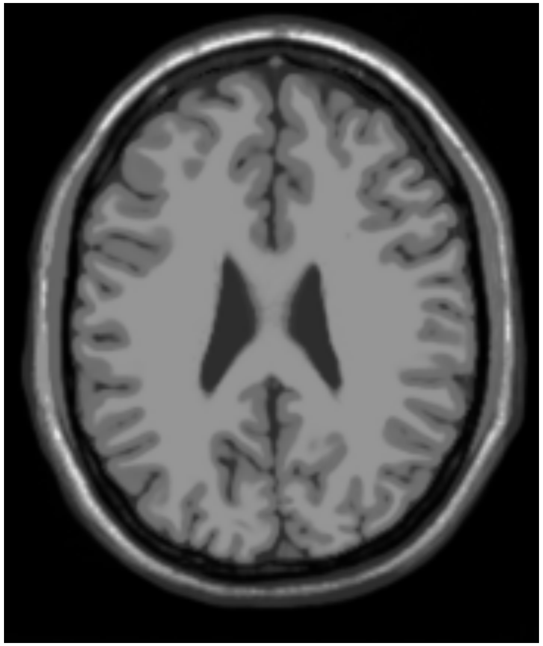
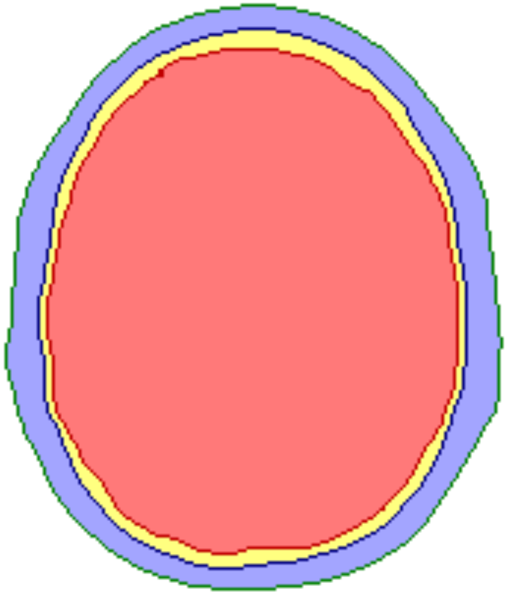
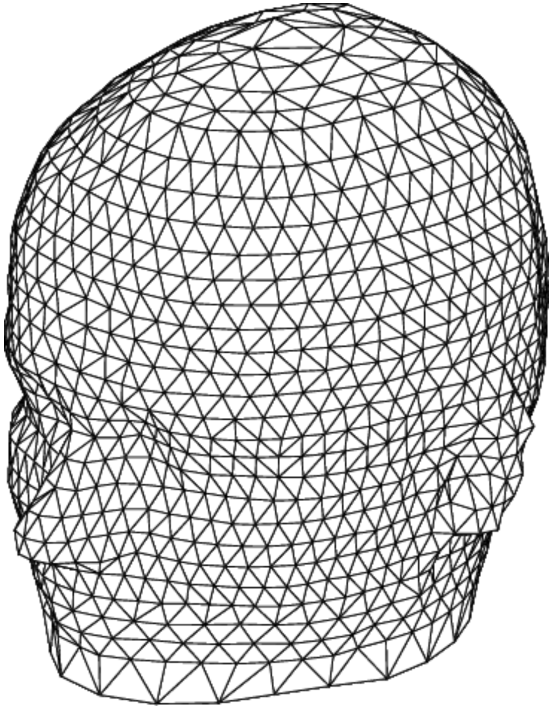
Triangulated surfaces describe boundaries



Volume conductor: Boundary Element Method

Construction of geometry

- segmentation in different tissue types
- extract surface description
- downsample to reasonable number of triangles

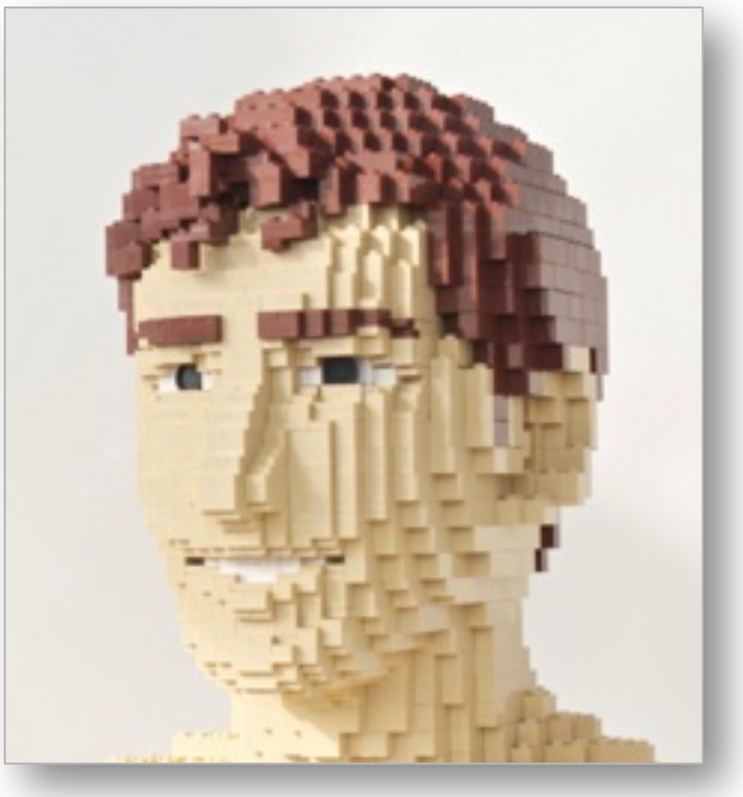




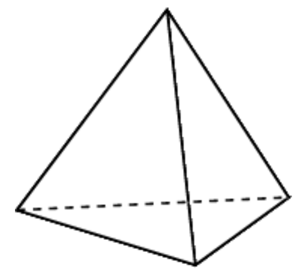
Volume conductor: Boundary Element Method

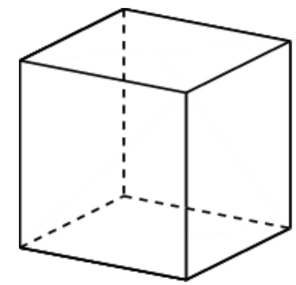
- Construction of geometry
  - segmentation in different tissue types
  - extract surface description
  - downsample to reasonable number of triangles
- Computation of model
  - independent of source model
  - only one lengthy computation
  - fast during application to real data
- Can also include more complex geometrical details
  - ventricles
  - holes in skull

Volume conductor: Finite Element Method

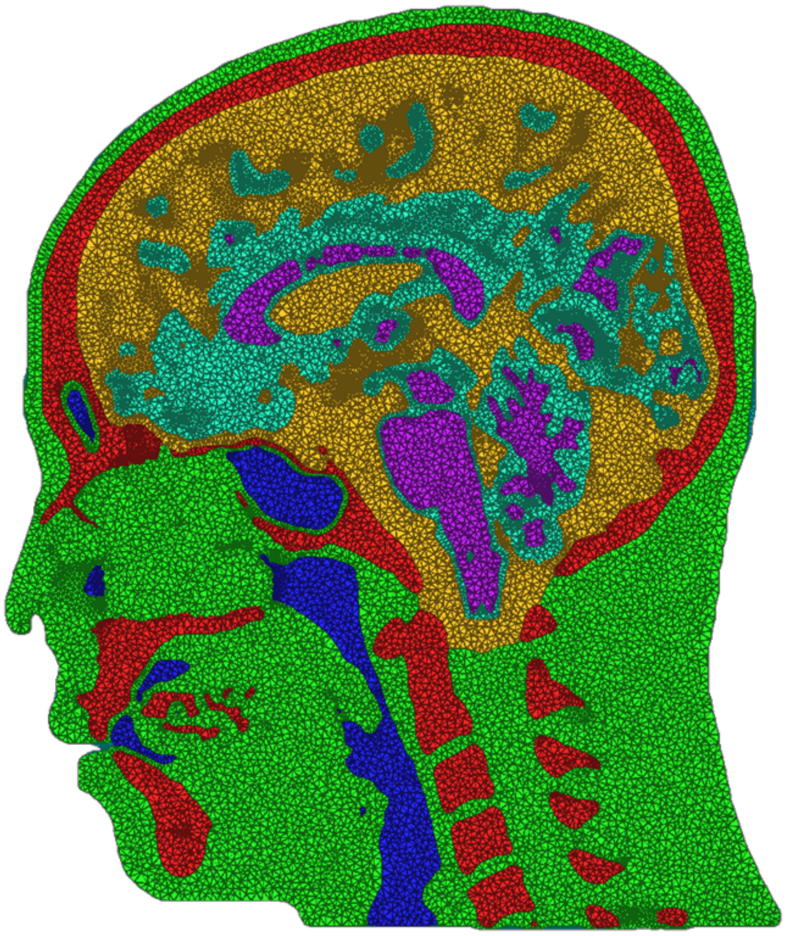
Tesselation of 3D volume in tetraeders or hexaheders



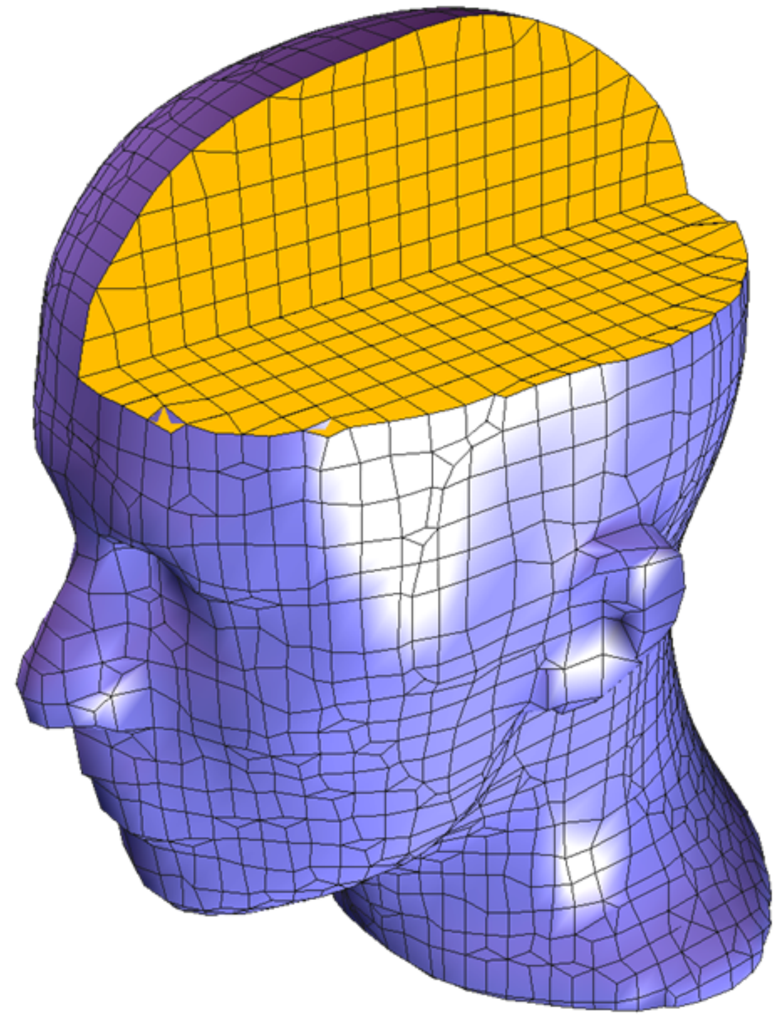




Volume conductor: Finite Element Method



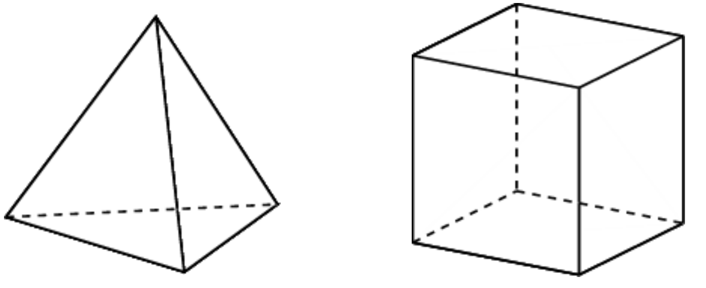
tetraeders



hexaheders

Volume conductor: Finite Element Method

Tesselation of 3D volume in tetraeders or hexaheders



Each element can have its own conductivity

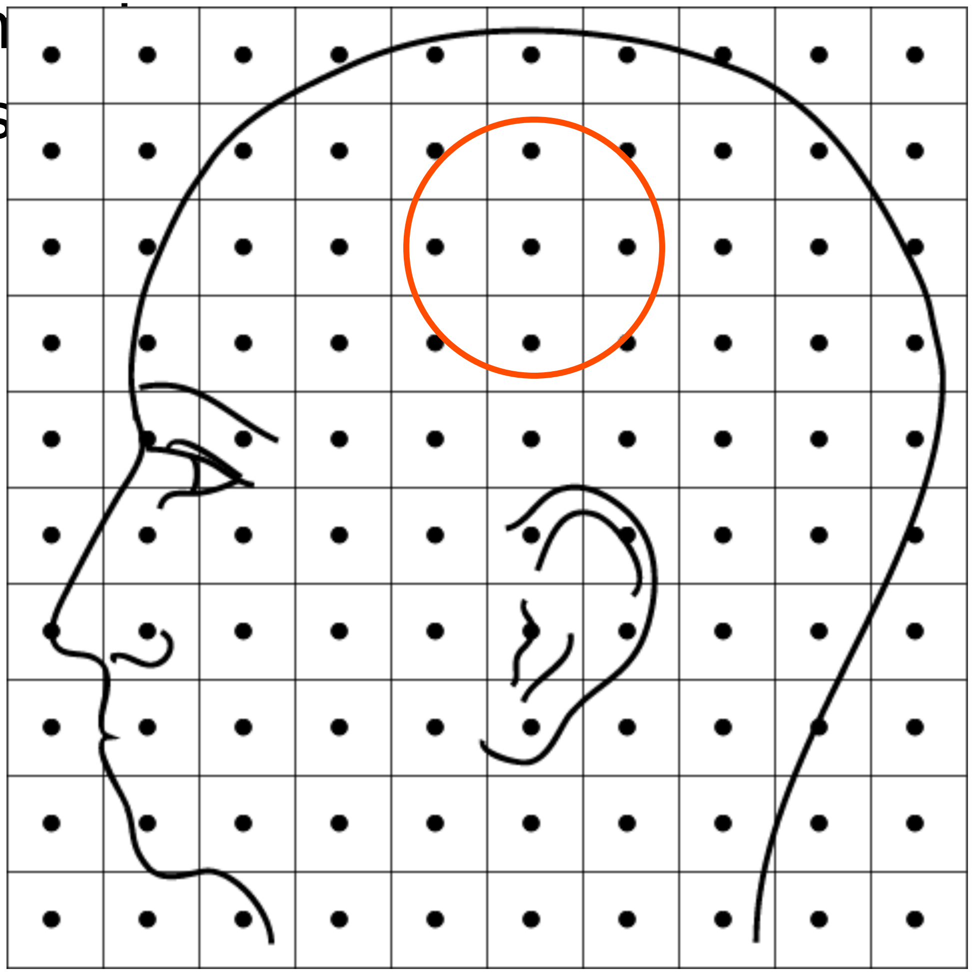
FEM is the most accurate numerical method but computationally quite expensive

Geometrical processing not as simple as BEM

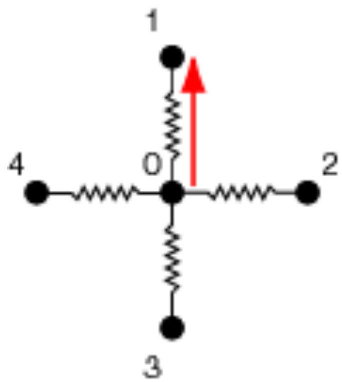
Volume conductor: Finite Difference Method

Easy to con

Not very us



Volume conductor: Finite Difference Method



$$I_1 + I_2 + I_3 + I_4 = 0$$
$$V = I*R$$
$\Rightarrow$

$$\Delta V_1/R_1 + \Delta V_2\,/R_2 + \Delta V_3\,/R_3 + \Delta V_4\,/R_4 = 0$$
$\Rightarrow$

$$(V_1\text{-}V_0)/R_1 + (V_2\text{-}V_0)/R_2 + (V_3\text{-}V_0)/R_3 + (V_4\text{-}V_0)/R_4 = 0$$

Volume conductor: Finite Difference Method

Unknown potential Vi at each node

Linear equation for each node

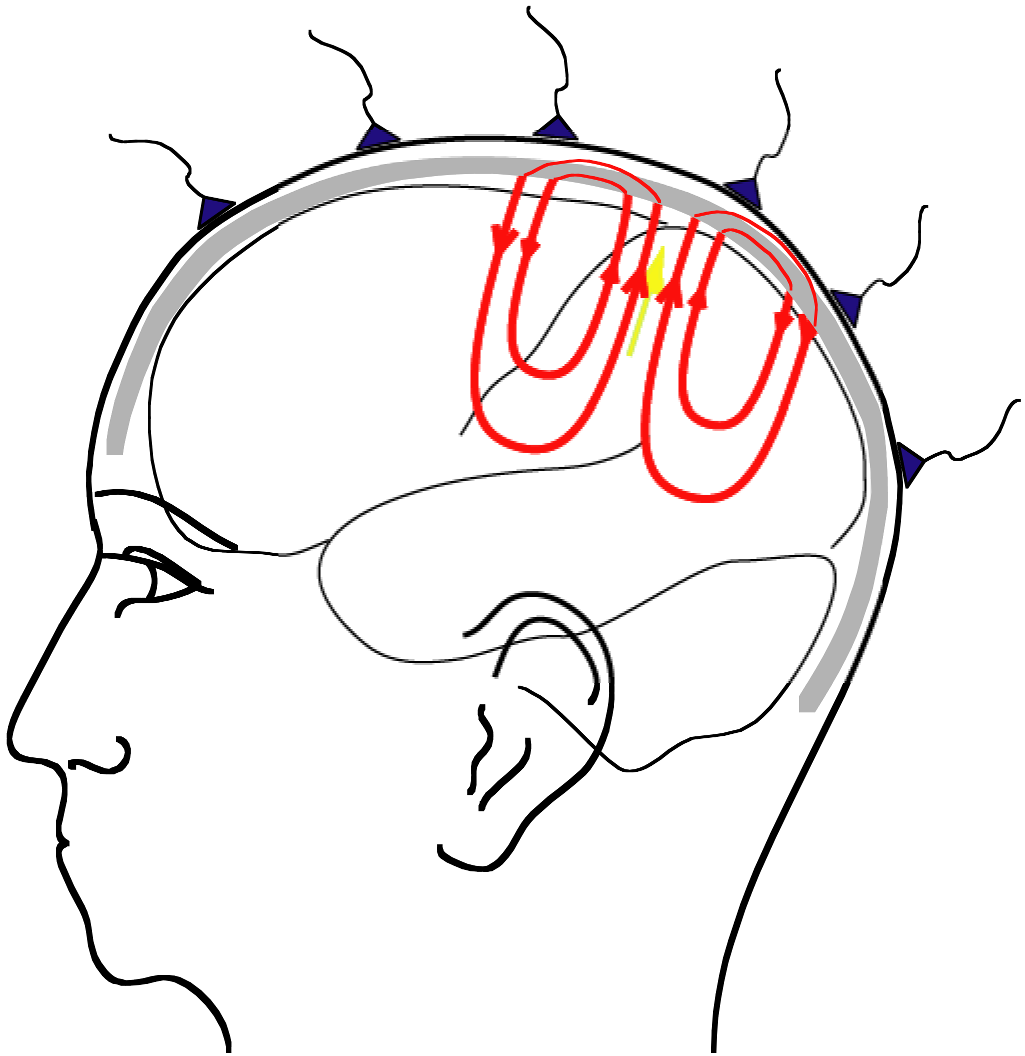
- approx. 100x100x100 = 1.000.000 linear equations
- just as many unknown potentials

Add a source/sink

- sum of currents is zero for all nodes, except
- sum of current is I+ for a certain node
- sum of current is I- for another node

Solve for unknown potential

EEG volume conduction



EEG volume conduction

- Potential difference between electrodes corresponds to current flowing through skin

- Only tiny fraction of current passes through skull

- Therefore the model should describe the skull and skin as accurately as possible

MEG volume conduction

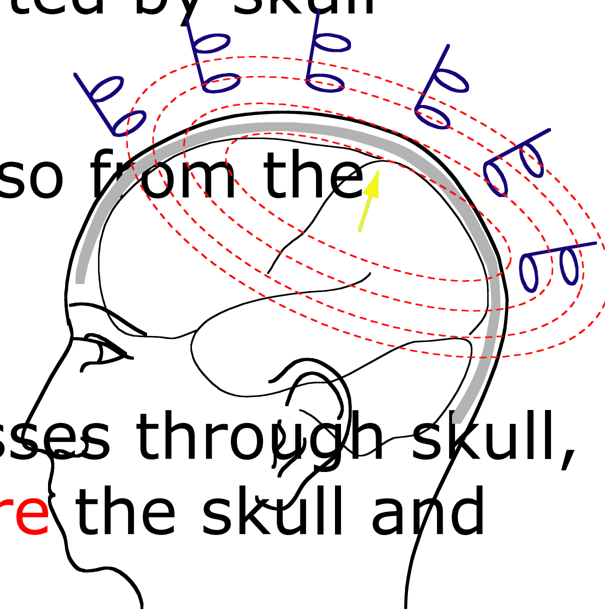
MEG measures magnetic field over the scalp

M … istorted by skull

M … ut also from the

O … passes through skull,

… gnore the skull and

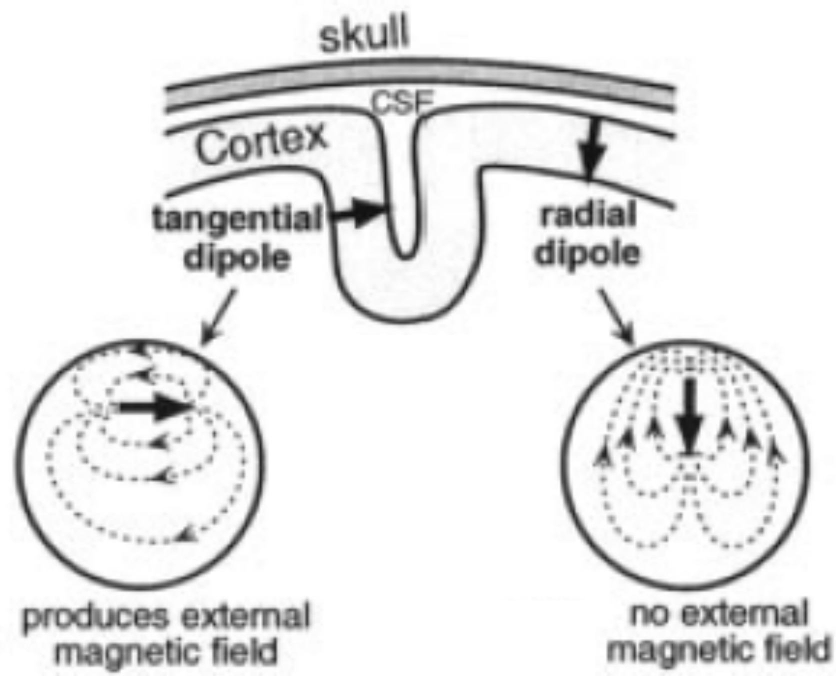


MEG volume conduction compared to EEG

EEG is measurement on scalp
potential difference due to volume currents

MEG field not affected by head

- magnetic field due to primary current (source)
- magnetic field due to secondary (volume) currents



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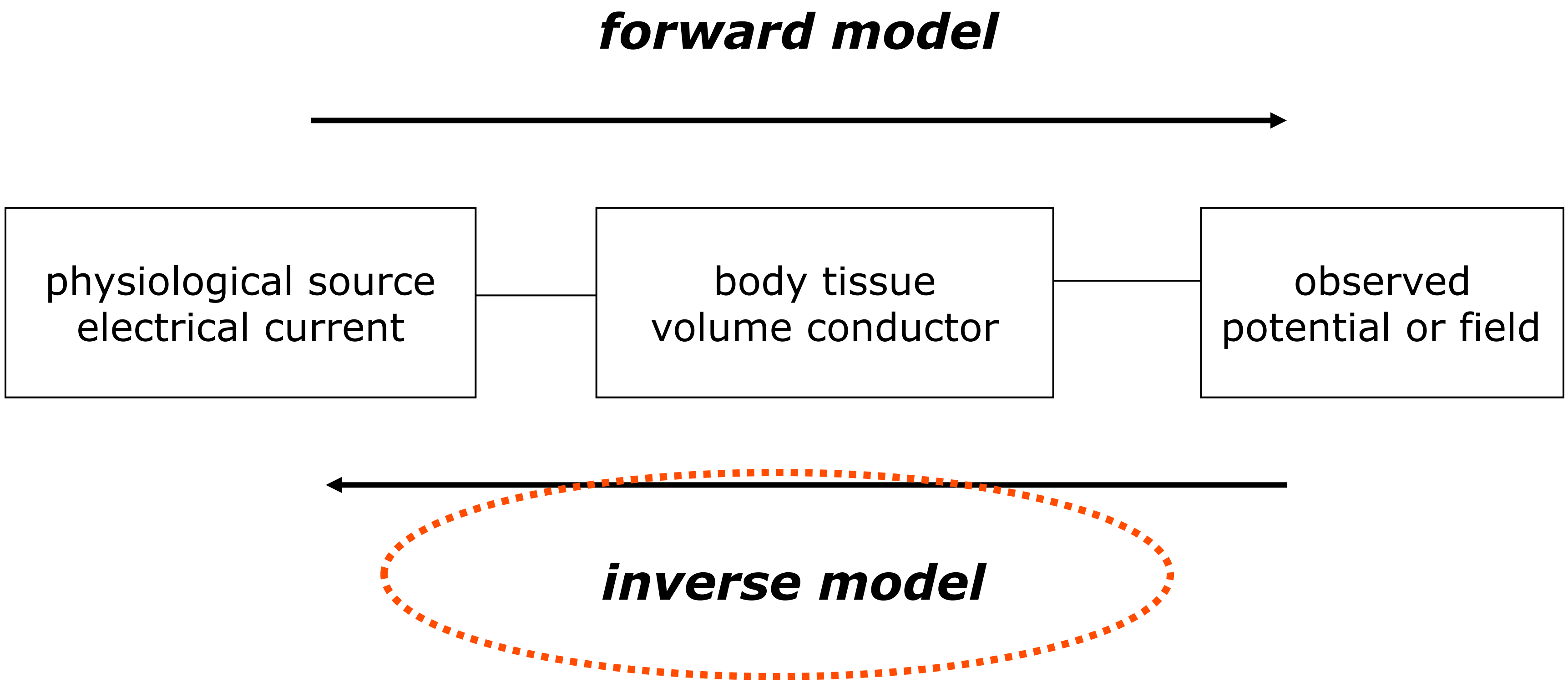
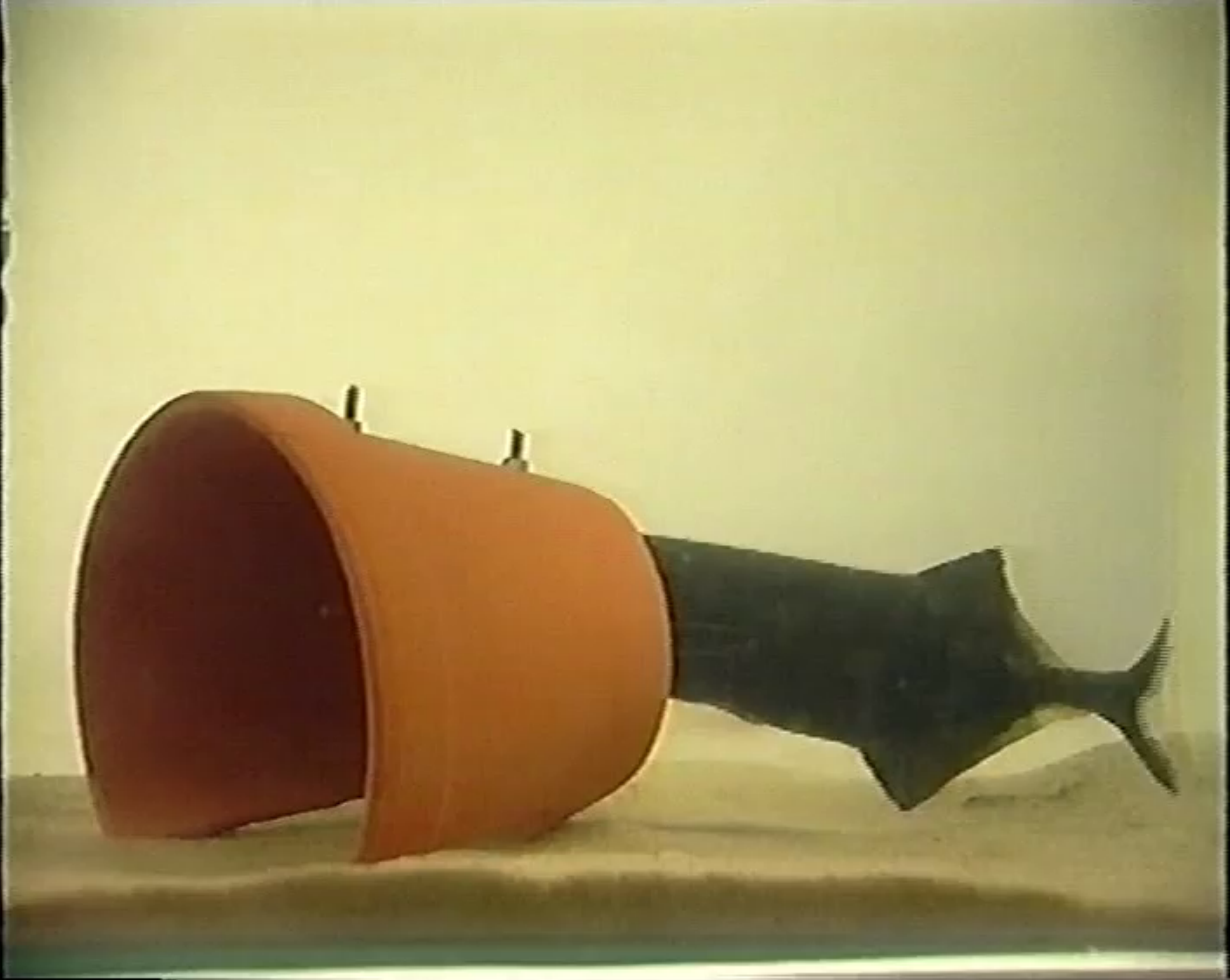
  - EEG versus MEG
- **Inverse modeling**

Biophysical source modelling: overview



Inverse localization: demo



Inverse methods

Single and multiple dipole models

Minimize error between model and measured potential/field

Distributed source models

Perfect fit of model to the measured potential/field

Additional constraint on source smoothness, power or amplitude

Spatial filtering

Scan the whole brain with a single dipole and compute the filter output at every location

Beamforming (e.g. LCMV, SAM, DICS)

Multiple Signal Classification (MUSIC)