Challenges in Brain Imaging

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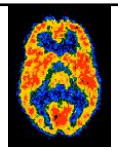
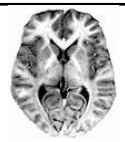
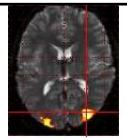
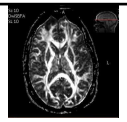
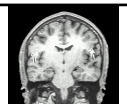
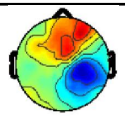
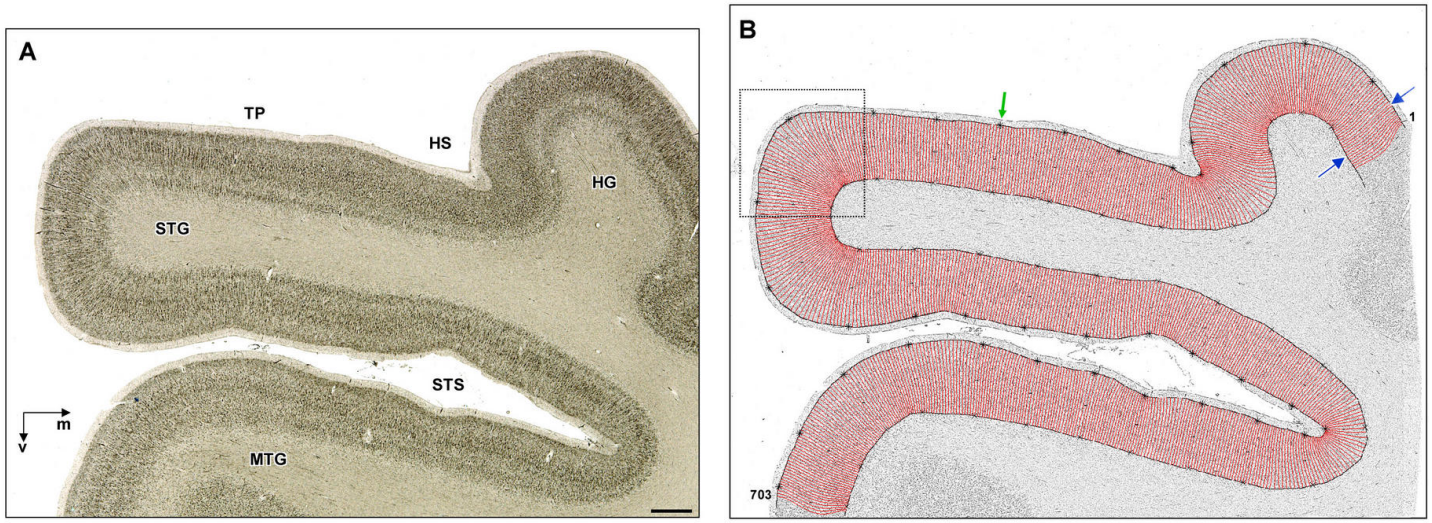
Content

1. Brain Imaging Techniques
2. Processing & Analysis
3. Visualization
4. Challenges for Mathematics and Computer Science

In Vivo Brain Imaging Techniques

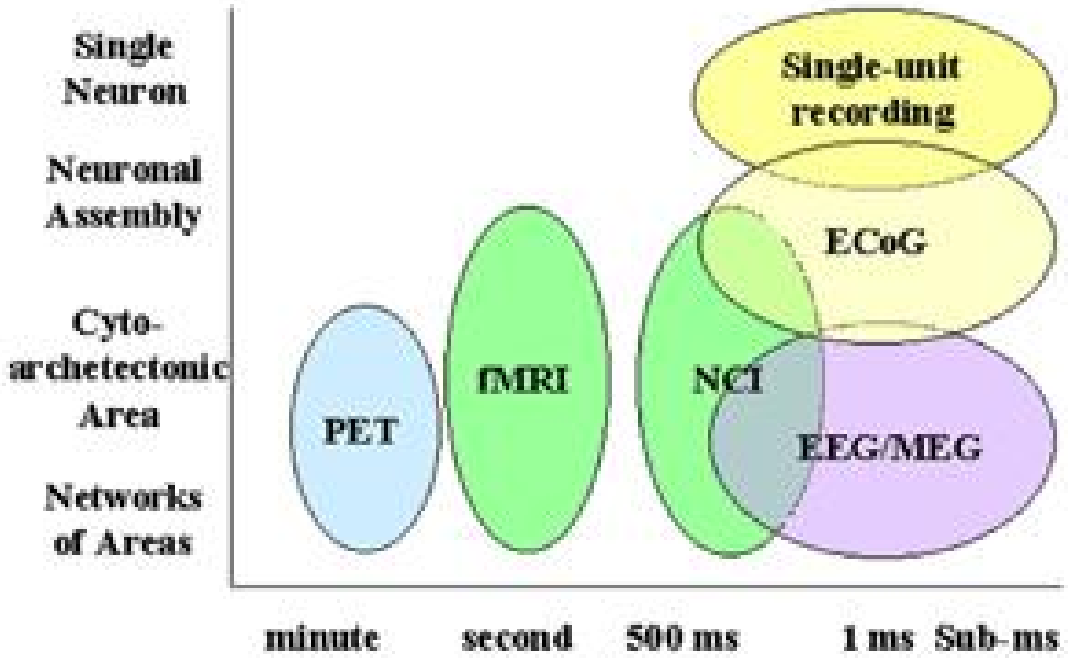
Technique	Exm	Represents:	Physical effect
CT		anatomy	X-ray attenuation
PET		metabolism	radioactive decay
MRI		anatomy	magnetic resonance
fMRI		metabolism	deoxygenation (BOLD)
DTI		nerve fibers	anisotropic diffusion
MEG		neuronal activity	magnetic signals
EEG		neuronal activity	electric signals

Microscopic imaging



Schleicher et al.: Quantitative architectectural analysis: a new approach to cortical mapping.

Resolution



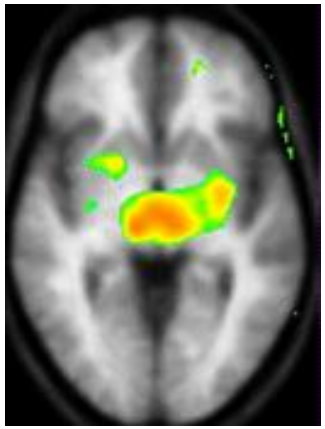
NCI:neuronal current imaging

ECoG: Electrocochleography

PET: Positron Emission Tomography

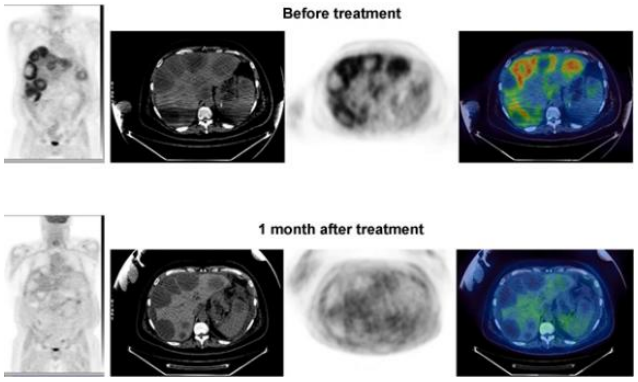
fMRI: Functional Magnetic Resonance Imaging

Multimodality Rendering

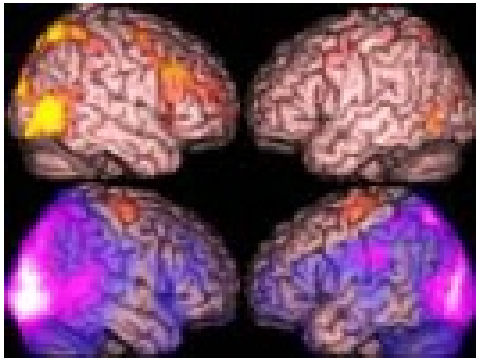


PET+MRI (©Wake Forest Univ.)

MRI+CT (©Able Softw. Corp.)



FDG-PET+CT (©HERMES MultiModality)

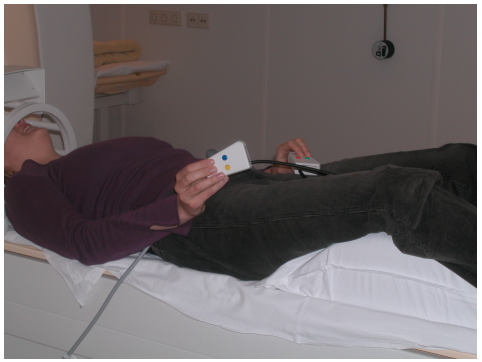


fMRI+MEG (©Aston Univ.)

Functional brain mapping

Goal: Assess significant brain activity during sensorimotor/cognitive task

volunteer in MRI scanner

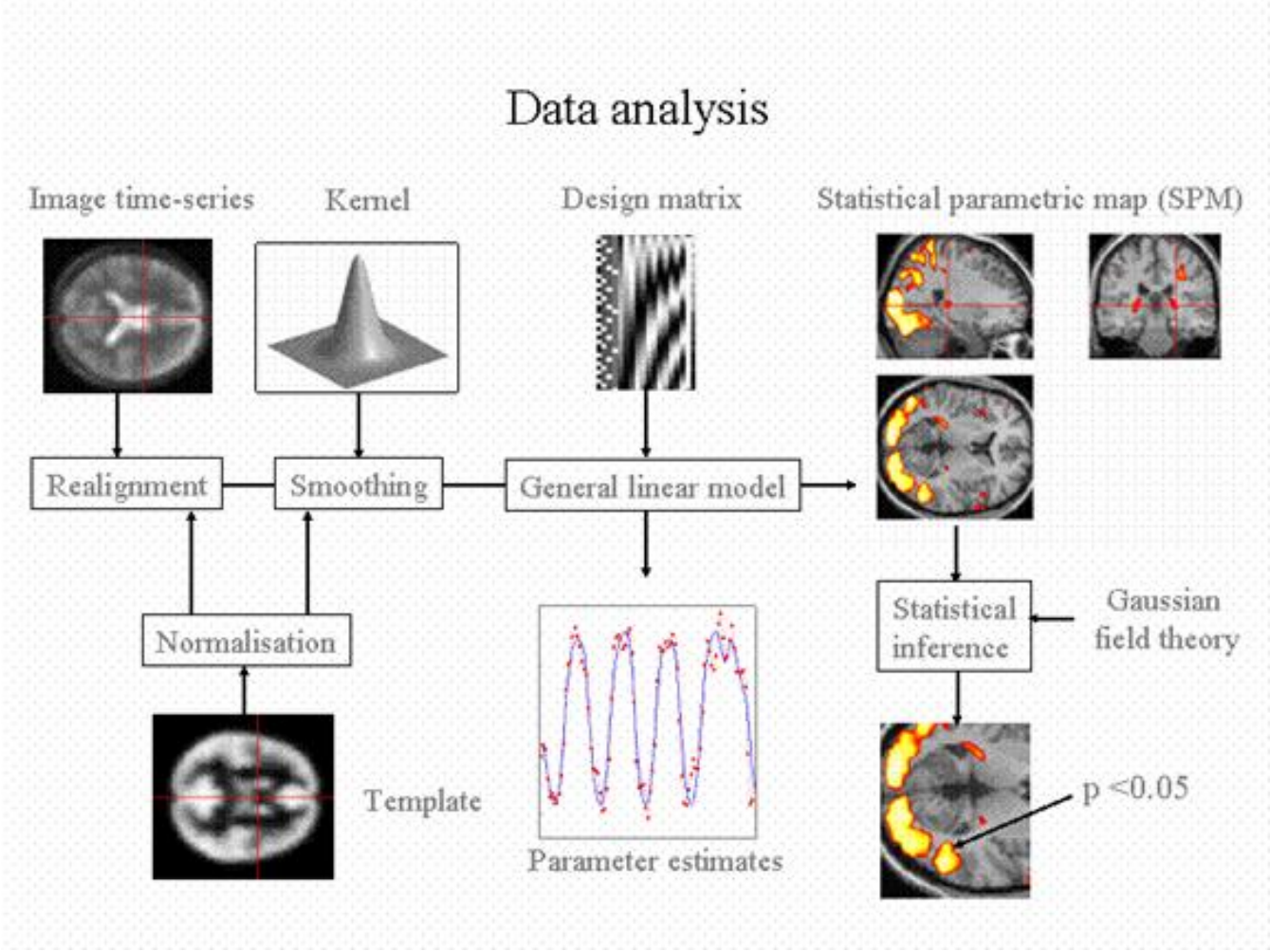


button box

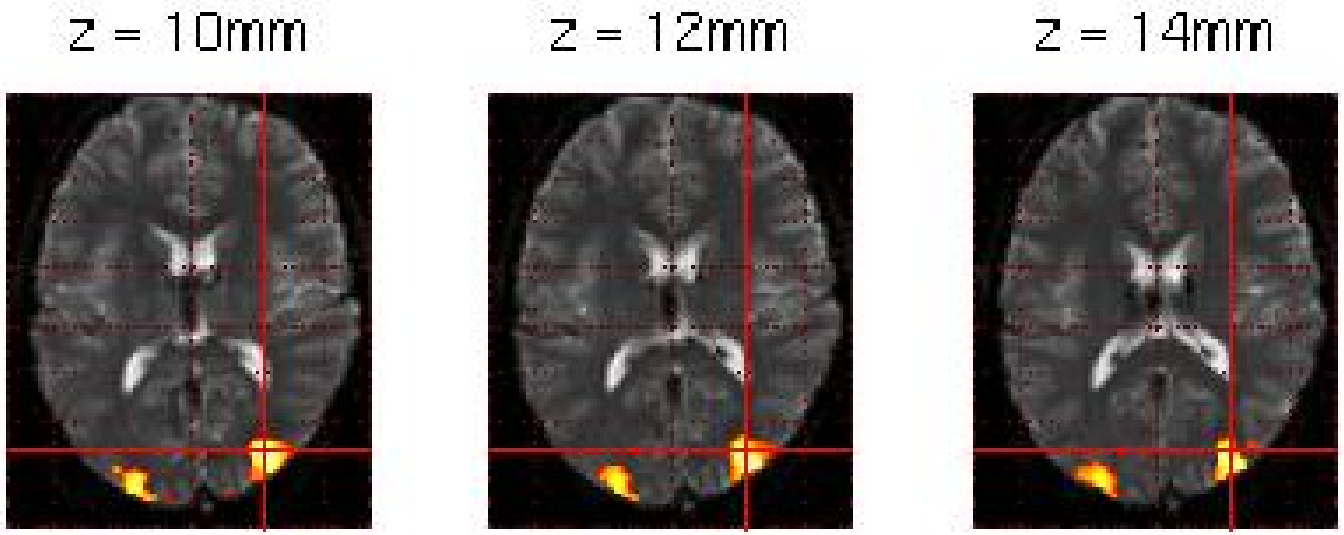
console + stimulus PC

Neuroimaging Center Groningen

Data Analysis Pipeline

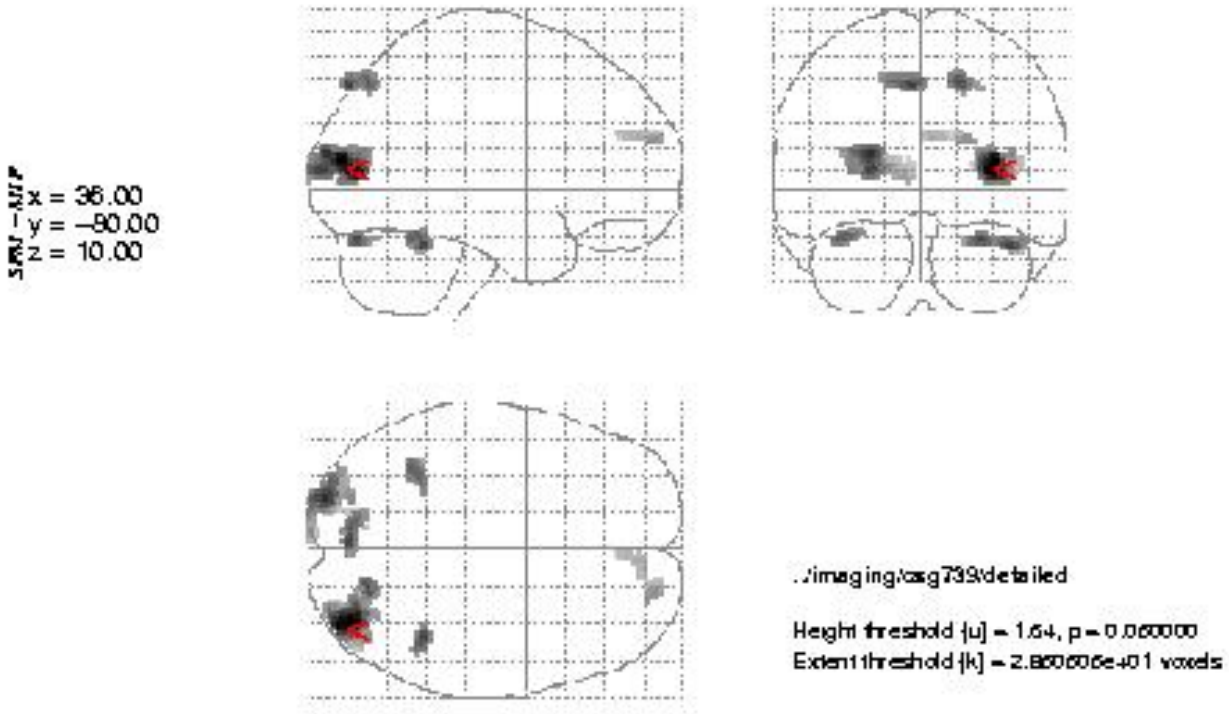


Statistical Parametric Mapping (SPM)



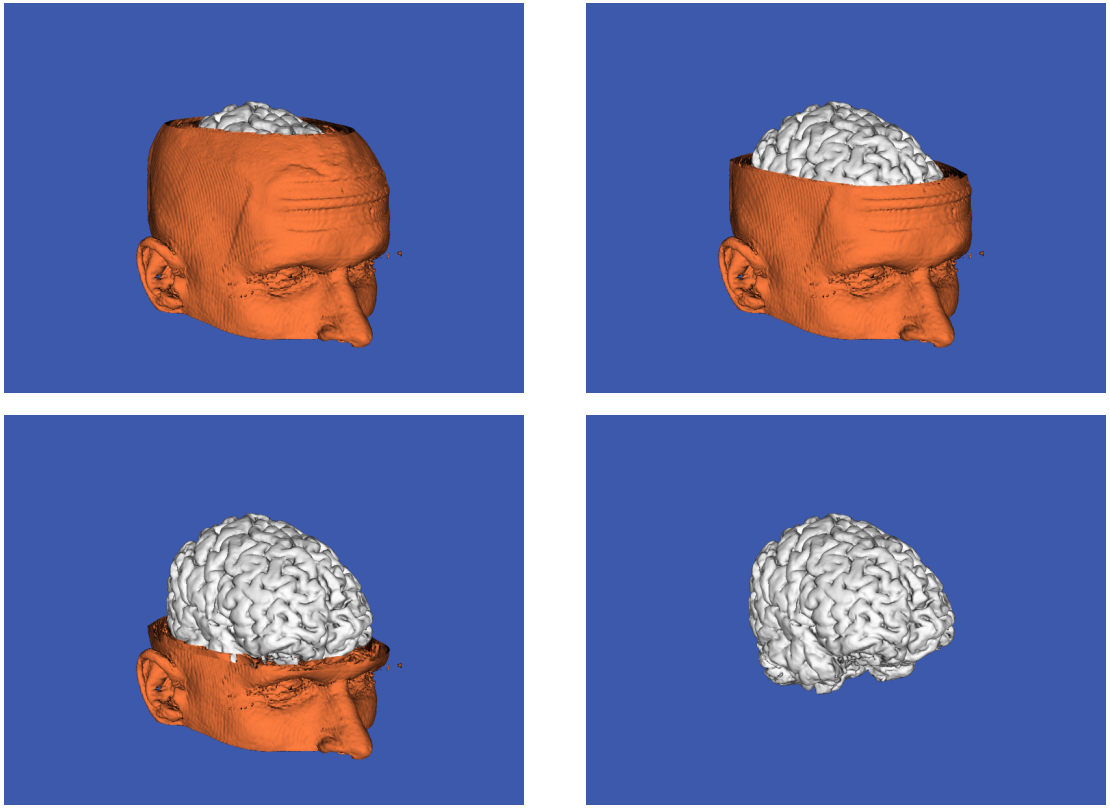
Functional activation (in colour) superimposed on anatomical data (grey value), for 3 different slices

Statistical Parametric Mapping (SPM)



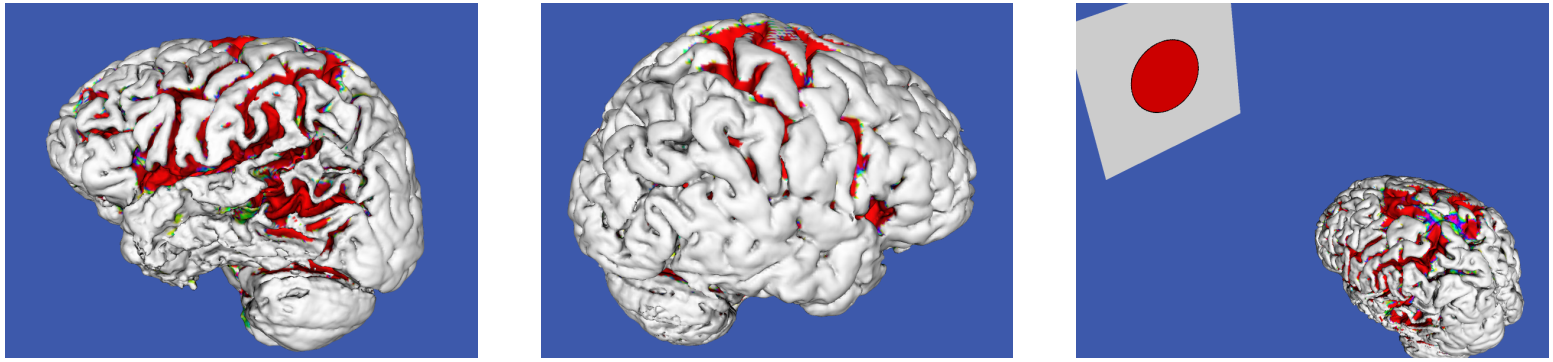
Orthogonal MIP projections on axial, coronal and sagittal planes with Talairach coordinates

MRI visualization



Cortex extraction

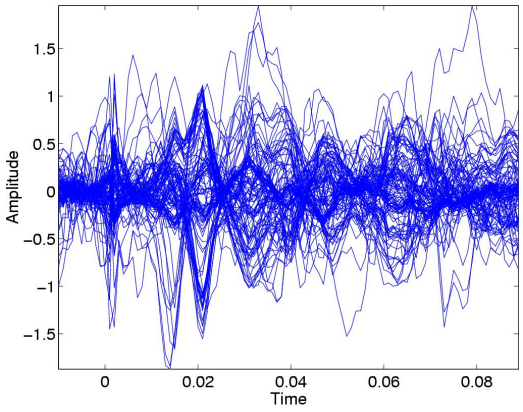
fMRI visualization



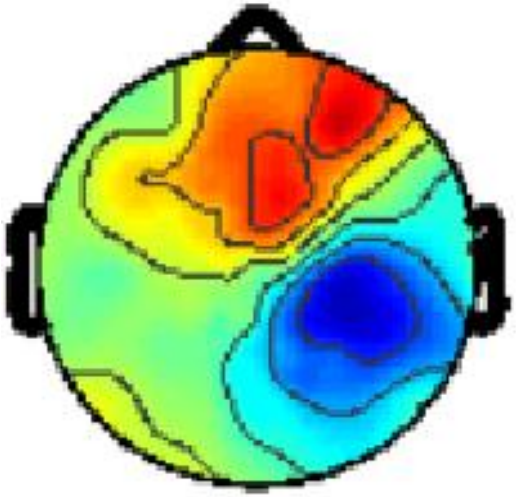
Visualization of brain activation by normal fusion

M. Westenberg, Institute for Mathematics and Computing Science, University of Groningen

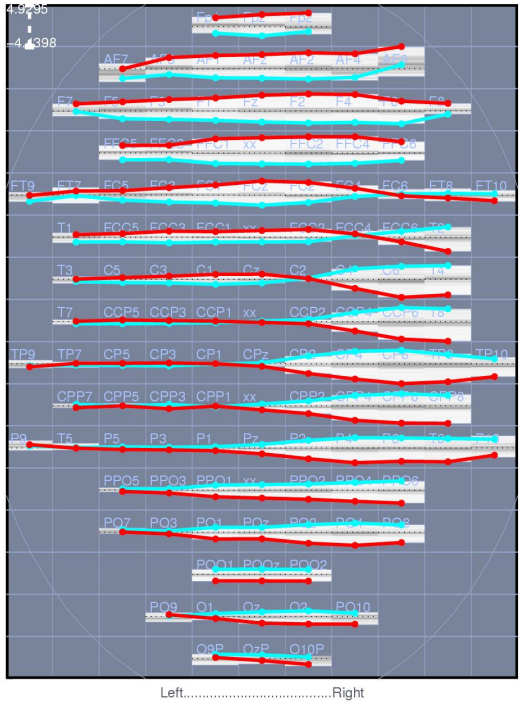
Multichannel EEG Visualization



butterfly plot



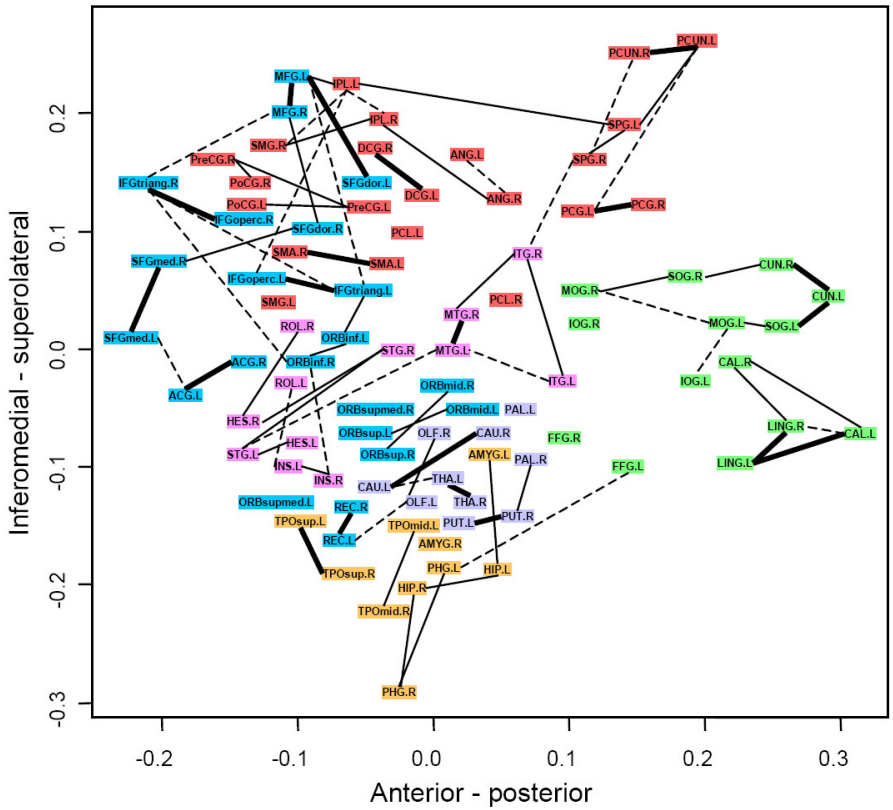
topographic maps



tiled parallel coordinates (*)

(*) M. ten Caat, N.M. Maurits, J.B.T.M. Roerdink, EuroVis2005

Whole brain connectivity

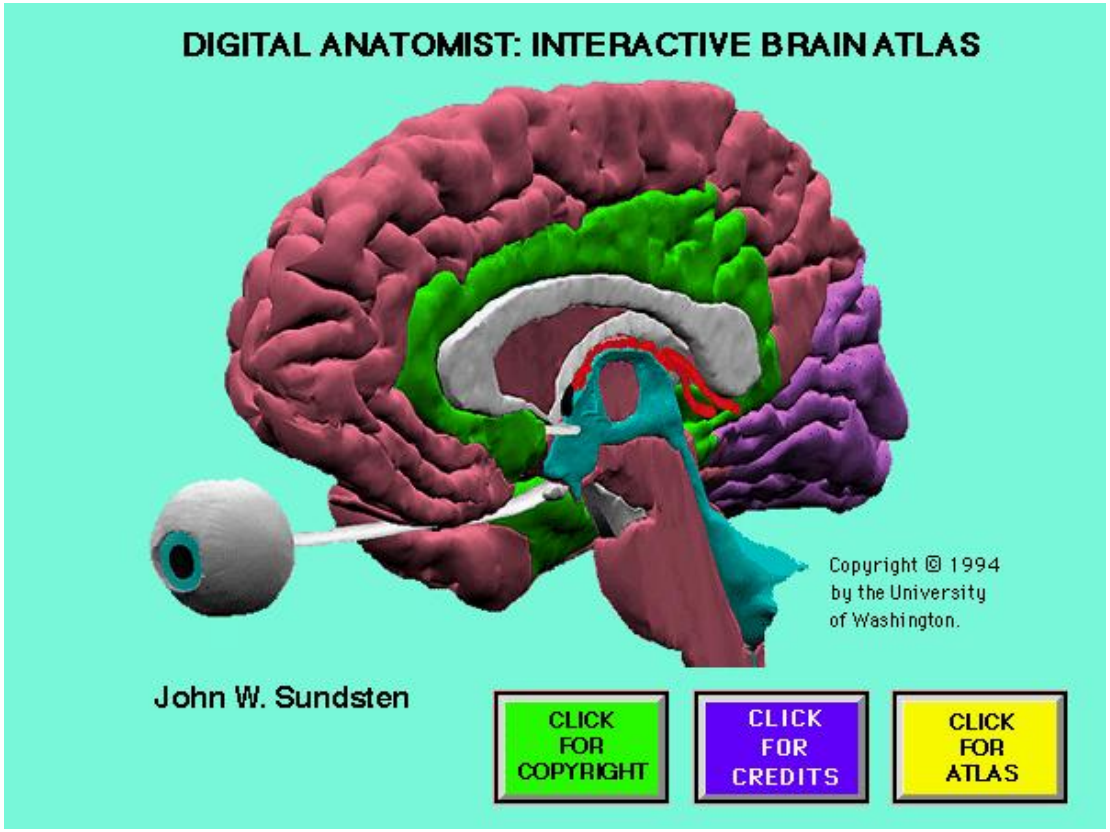


Resting state fMRI: correlation analysis of regional time series, hierarchical clustering and multidimensional scaling

Salvador et al., Neurophysiological architecture of functional magnetic resonance images of human brain,

Cereb Cortex, 2005,15(9):1332-42.

Interactive Brain Atlases



Digital Anatomist Project. Dept. Biological Structure, University of Washington, Seattle.

Methodological Issues

Task	Mathematical & Computational Methods
Tomographic reconstruction	backprojection, Fourier inversion, algebraic reconstruction techniques
Realignment	numerical function optimization
Noise Reduction	(non)linear filtering, statistical optimization, random fields models, Fourier & wavelet transforms
Normalization	(non)linear deformation, optimization
Segmentation	morphological filters, level set methods, probability models, template databases
Mapping	compartmental models, deconvolution, statistical parametric mapping (SPM)
Visualization	surface & volume rendering, data fusion, data compression
Interaction	visualization, simulation, GUIs, virtual reality
Network analysis	graph theory, graph visualization, dynamical models

Challenges

- Variety of brain imaging techniques over large range of spatial and temporal scales
- Extensive data processing chains: different techniques, many (hidden) parameters, implicit model assumptions
- Large variety of (sparsely documented) software tools
- Biological variation: need image databases over collections of imaging conditions, people, populations; need probabilistic brain models
- High costs of brain imaging techniques
- Interaction between people from very diverse backgrounds needed