

Connectomics

Tools and Applications

Master Thesis Presentation
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Stephan Gerhard

ETH

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

EPFL
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

CHUV

Supervisors:

Prof. Jean-Philippe Thiran

Signal processing Laboratory 5, EPFL

Dr. Patric Hagmann

Department of Radiology, CHUV

Mentor:

Dr. Daniel Kiper

Institute of Neuroinformatics, ETHZ



by Victor Juhasz

Outline

Introduction

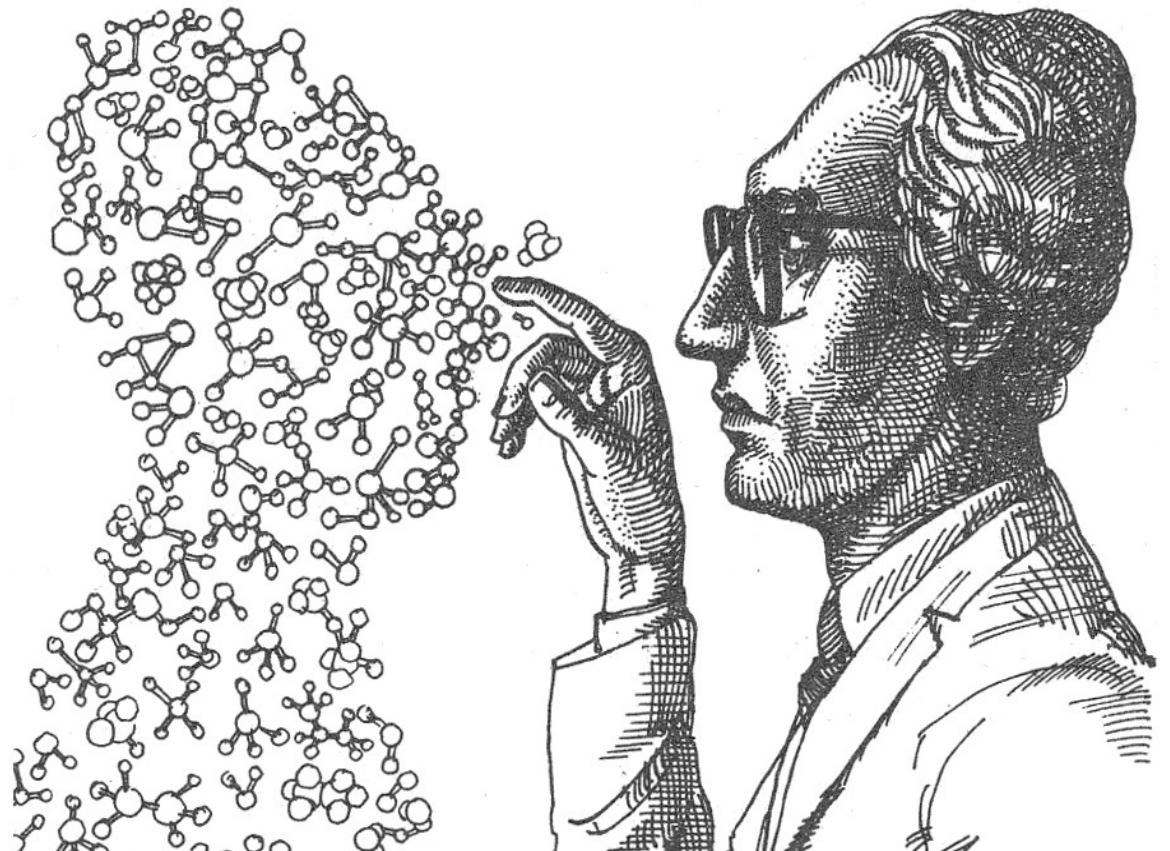
2 Tools

- ConnectomeViewer
- ConnectomeWiki

2 Applications

- Mesoscale level
- Microscale level

Outlook



by Victor Juhasz

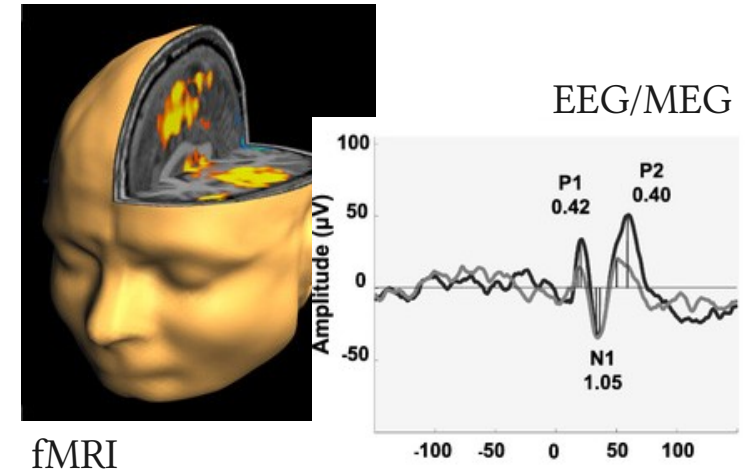
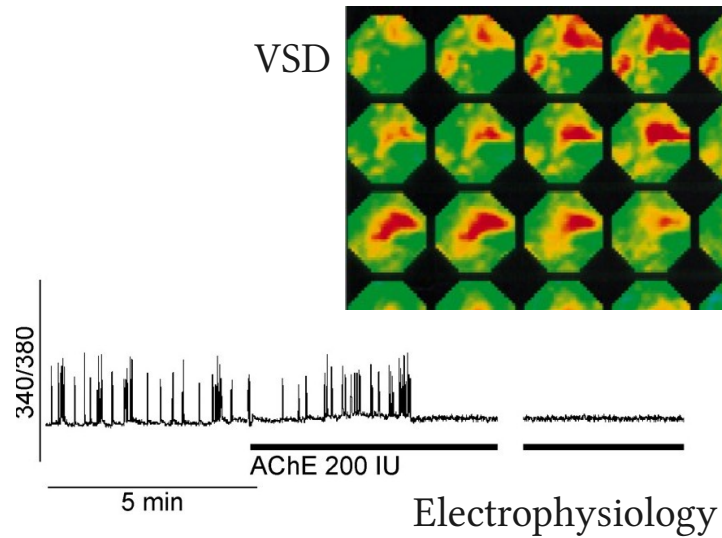
What is Connectomics?

Merriam-Webster Dictionary

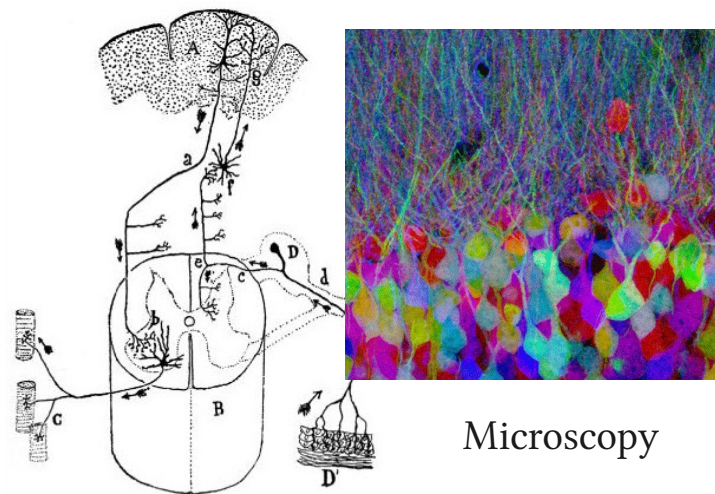
„A branch of biotechnology concerned with applying the techniques of computer-assisted image acquisition and analysis to the structural mapping of sets of neural circuits or to the complete nervous system of selected organisms using high-speed methods, with organizing the results in databases, and with applications of the data.“

Structure and Function

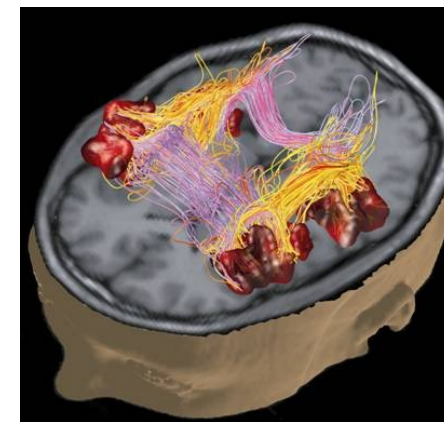
Function



Structure



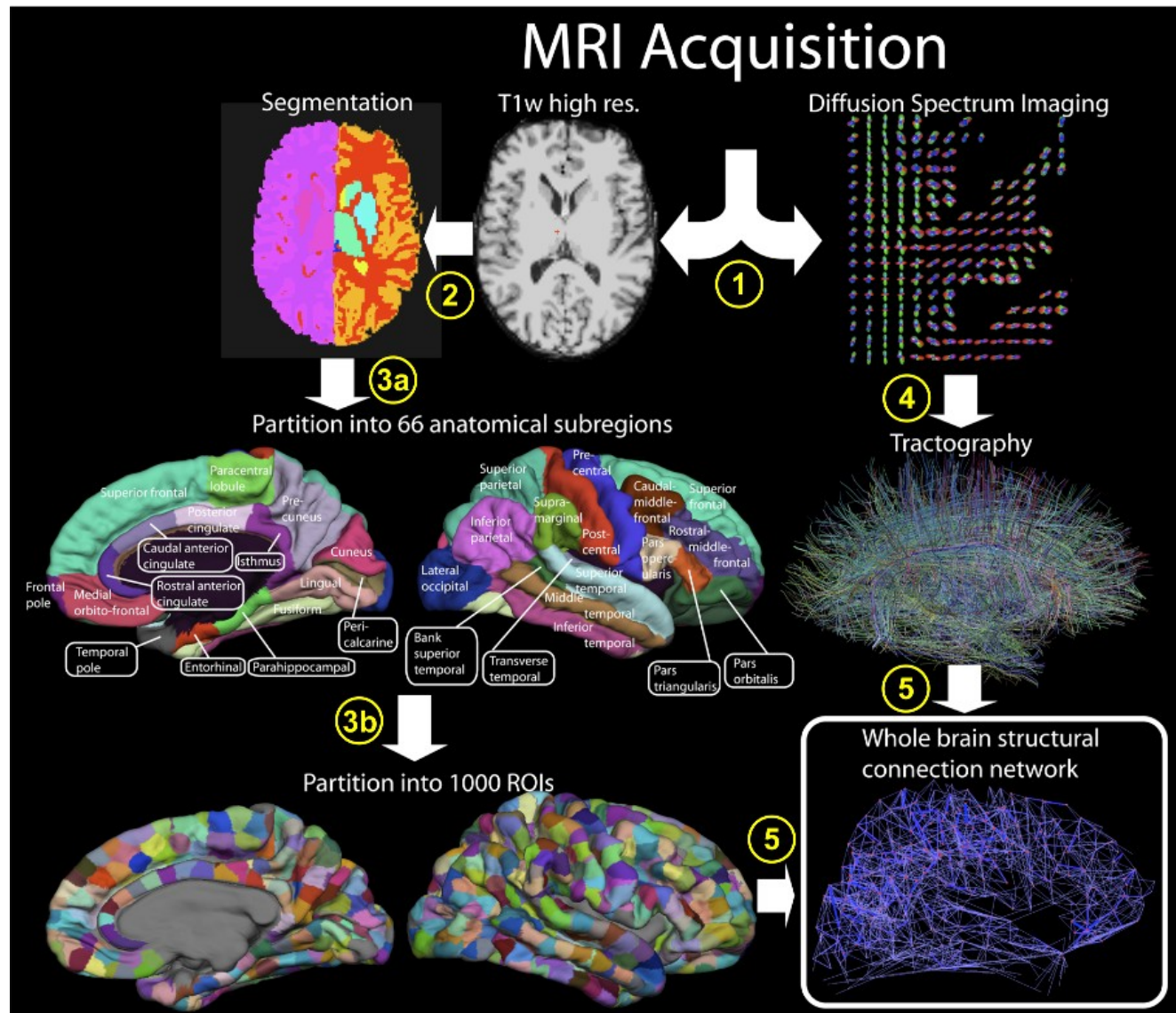
Cellular level



Mesoscale level

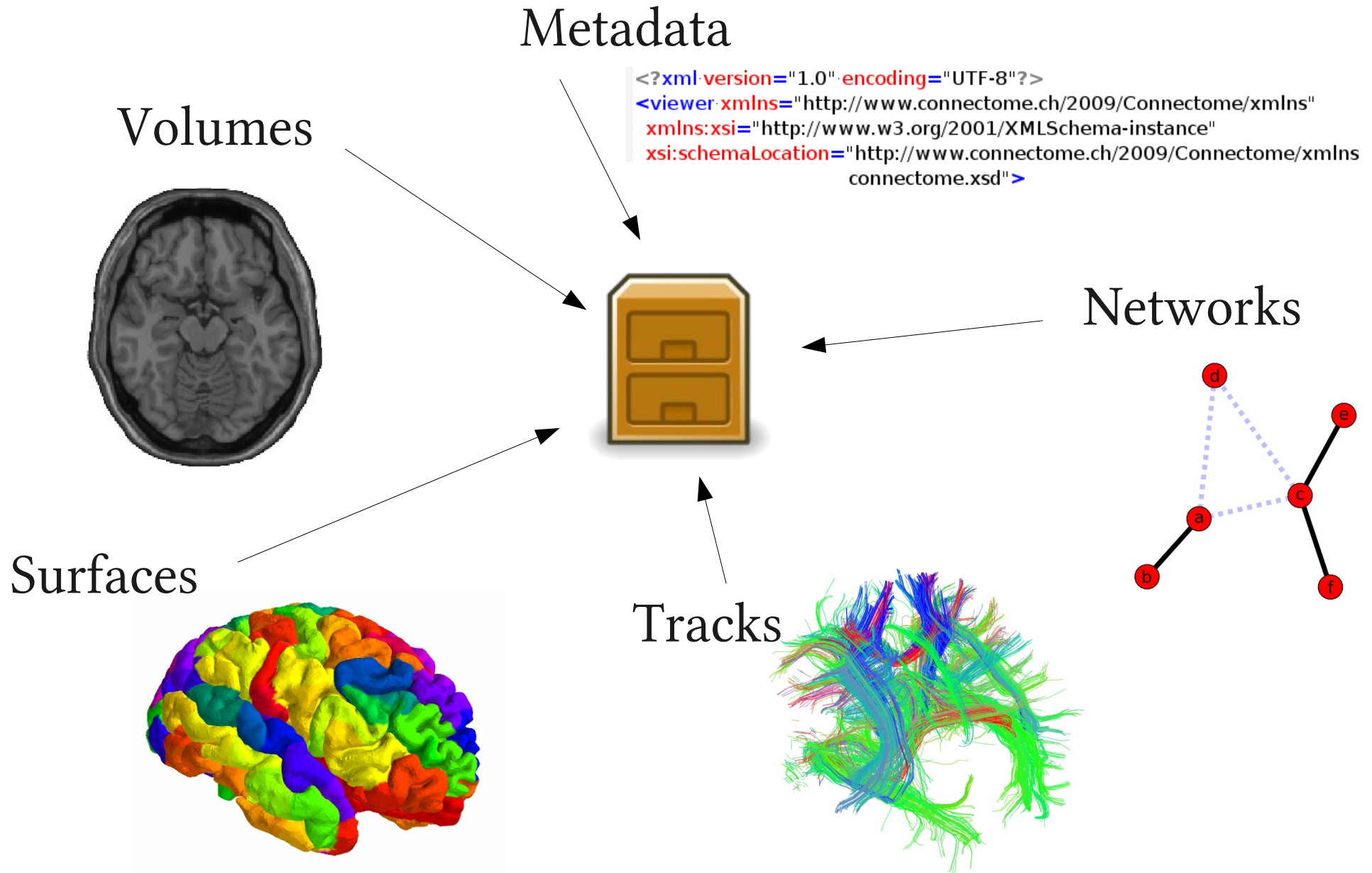
Connectome Mapping Pipeline

From raw data to connectomes



Connectome File Format

Datatypes, come together - right now.



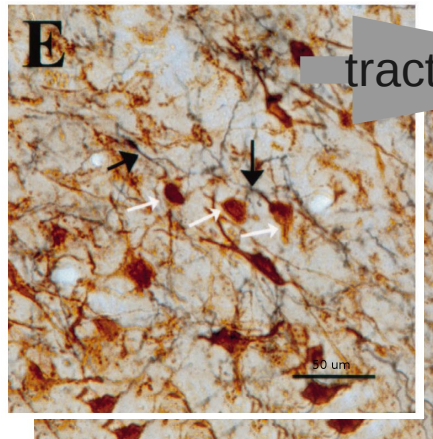
Connectome File Format

Cellular level datatypes are the same

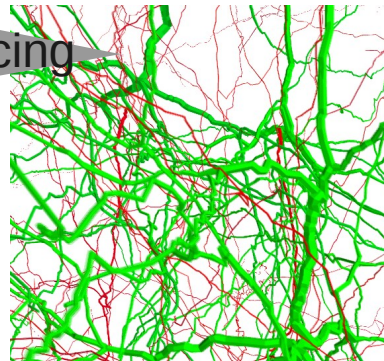
Volumes

Surfaces

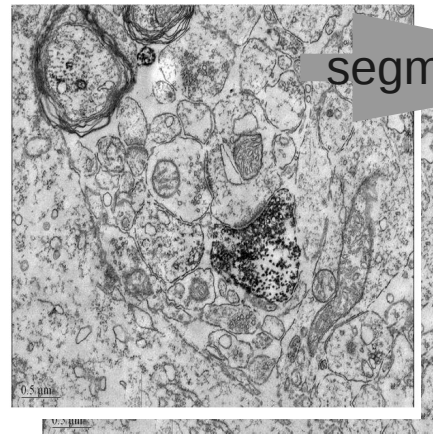
Light
Microscopy



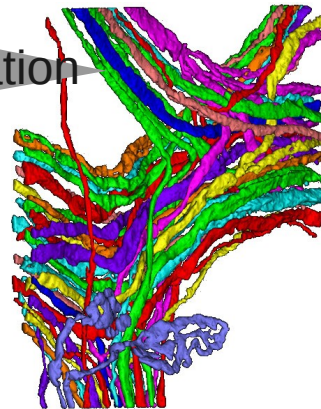
tract tracing



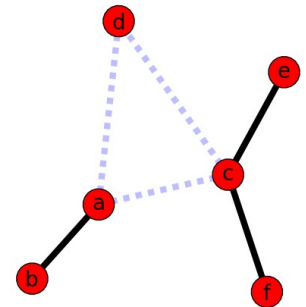
Electron
Microscopy



segmentation



Networks



ConnectomeViewer

Visualization and Analysis of Connectomes

Deploy the Connectome File Format

Python-based (approx. 4500 lines of code), GPL

Modular plugin architecture for extensibility

Interactivity

- 3D View of networks and surfaces

- Select Nodes, Set Edge Attributes, Thresholding

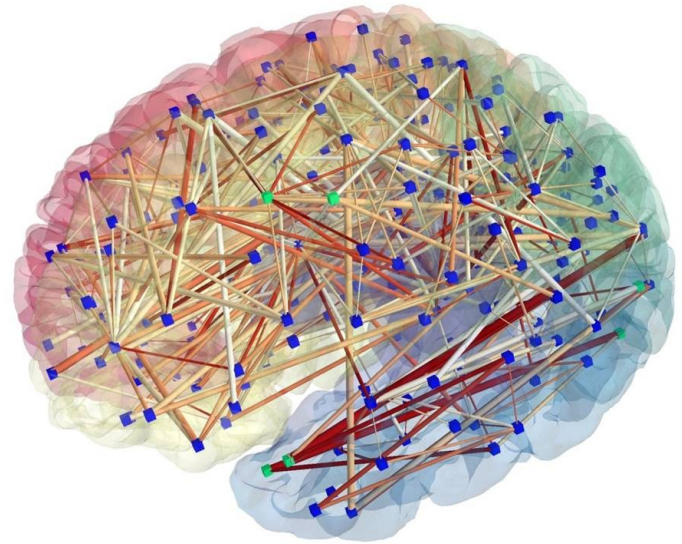
- Build Visualization Pipelines (Mayavi plugin)

Fully Scriptable

- Write visualization and analysis scripts for the data

- Using scientific libraries (e.g. for network analysis, plotting)

Interface to TrackVis (for tractography results)



2nd Price Biomedical Visualization
Contest 2009 Kitware

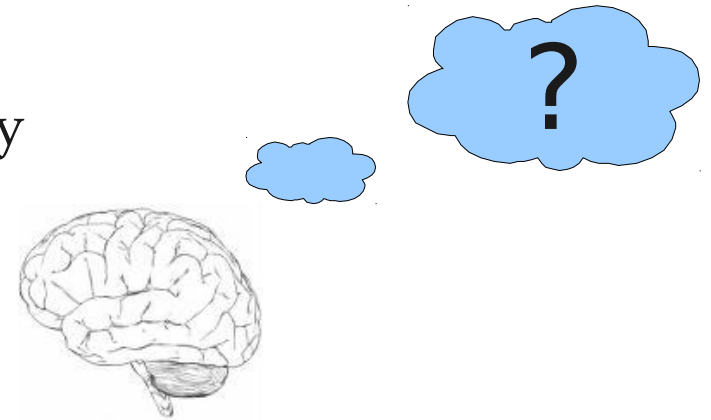
ConnectomeWiki

Collaborative semantic-wiki web platform

Like Wikipedia, but for mesoscale neuroanatomy

Brain **Region** and Brain **Connection** pages

Usable **across species**



Species	Brain Regions	Brain Region Connections
Homo sapiens		
<i>Foundational Partition</i>	876	65
<i>Lausanne Partition</i>	2006	0
Macaca mulatta	317	1
Taeniopygia guttata	40	40
Rattus norvegicus	20	120
Felis catus	5	0

Contains different **partitioning schemes**

Build **semantic search queries**

Links to **relevant literature**

Integrated in the *Neuroscience Information Framework* (soon)

DEMO

... and now, two possible applications

Application

Human Developmental Project ⁽¹⁾

Questions:

Are there age-dependent changes in myelination strength in humans?

Are these changes spatially non-uniform?

Study: N = 34 subjects (19 female, 15 male)

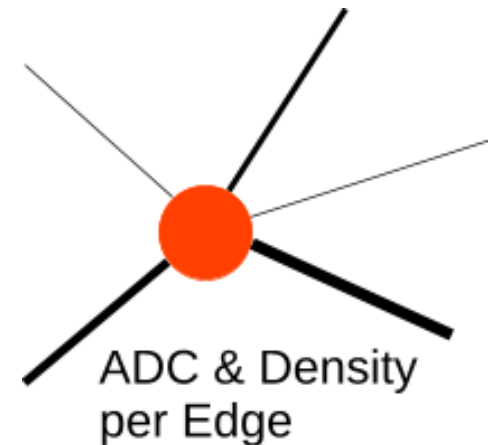
Age from 2 to 18 years

Connectome Mapping Pipeline

Define **Inverse Myelination Strength** per node/ROI: $M(t)$

Using apparent diffusion coefficient (ADC) and density (d)

$$M(t) = \frac{1}{N} \sum_i ADC_{mean_i}(t) \frac{d_i(t)}{\sum_j d_j(t)}$$

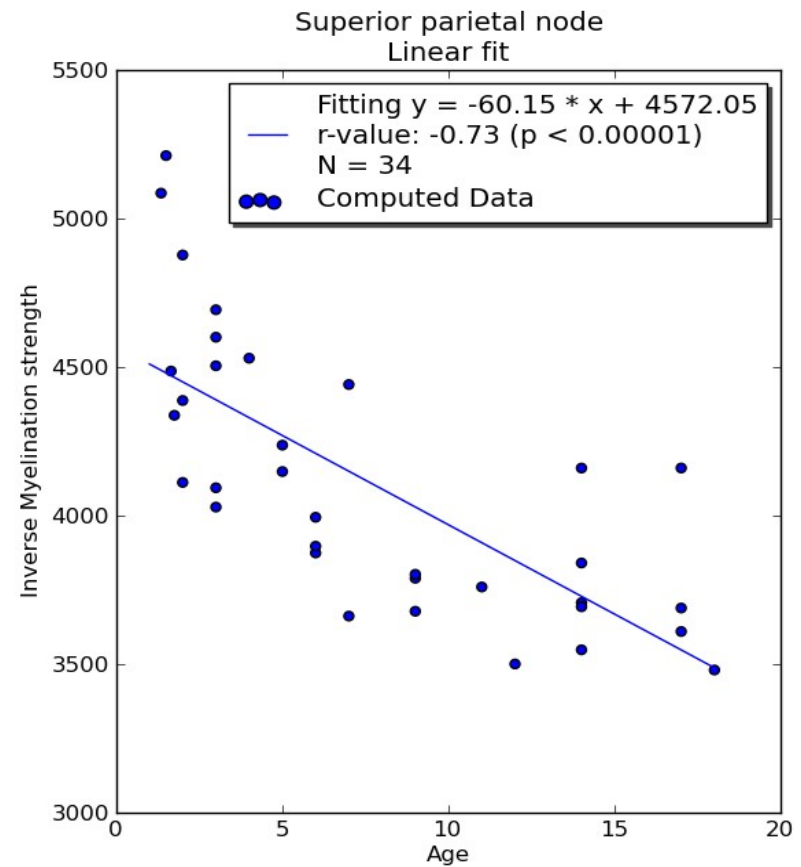
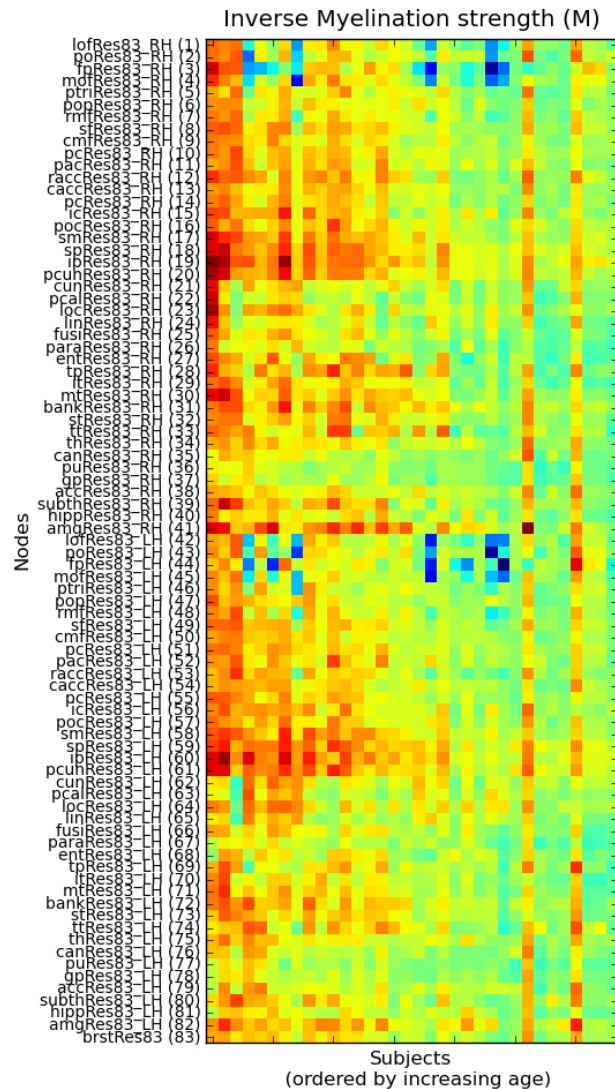


Reference:

Mapping the development of the human connectome. P. Hagmann, O. Sporns, S. Gerhard, R. Pienaar, J-P. Thiran, L. Cammoun, N. Madan, and P. E. Grant, *ISMRM 2010 conference abstract* (Accepted)

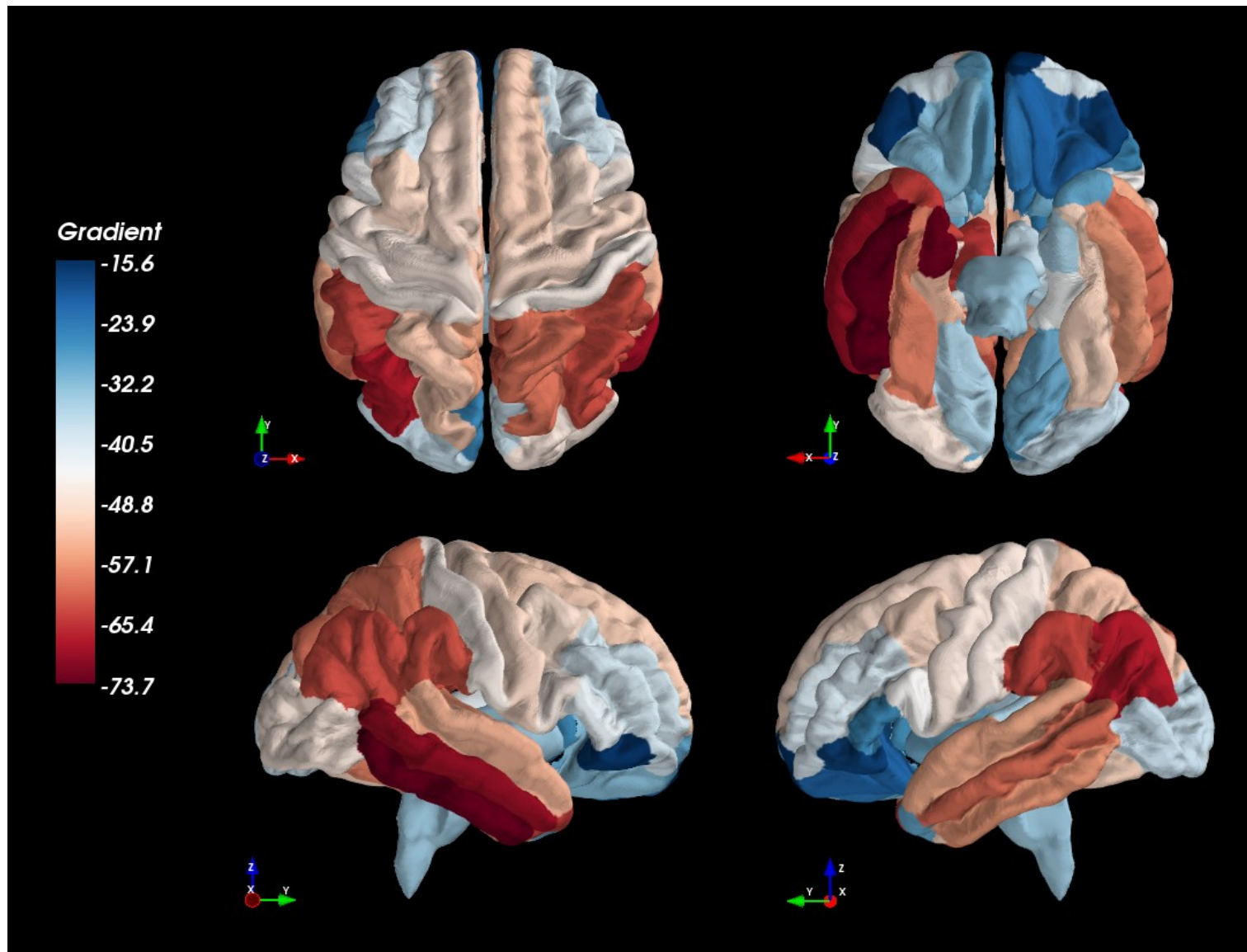
Developmental Project ⁽²⁾

Results



Developmental Project ⁽³⁾

Results



Conclusion

Significant age-dependent changes in myelination strength found

Changes are spatially non-uniform and are more pronounced for parietal and temporal areas

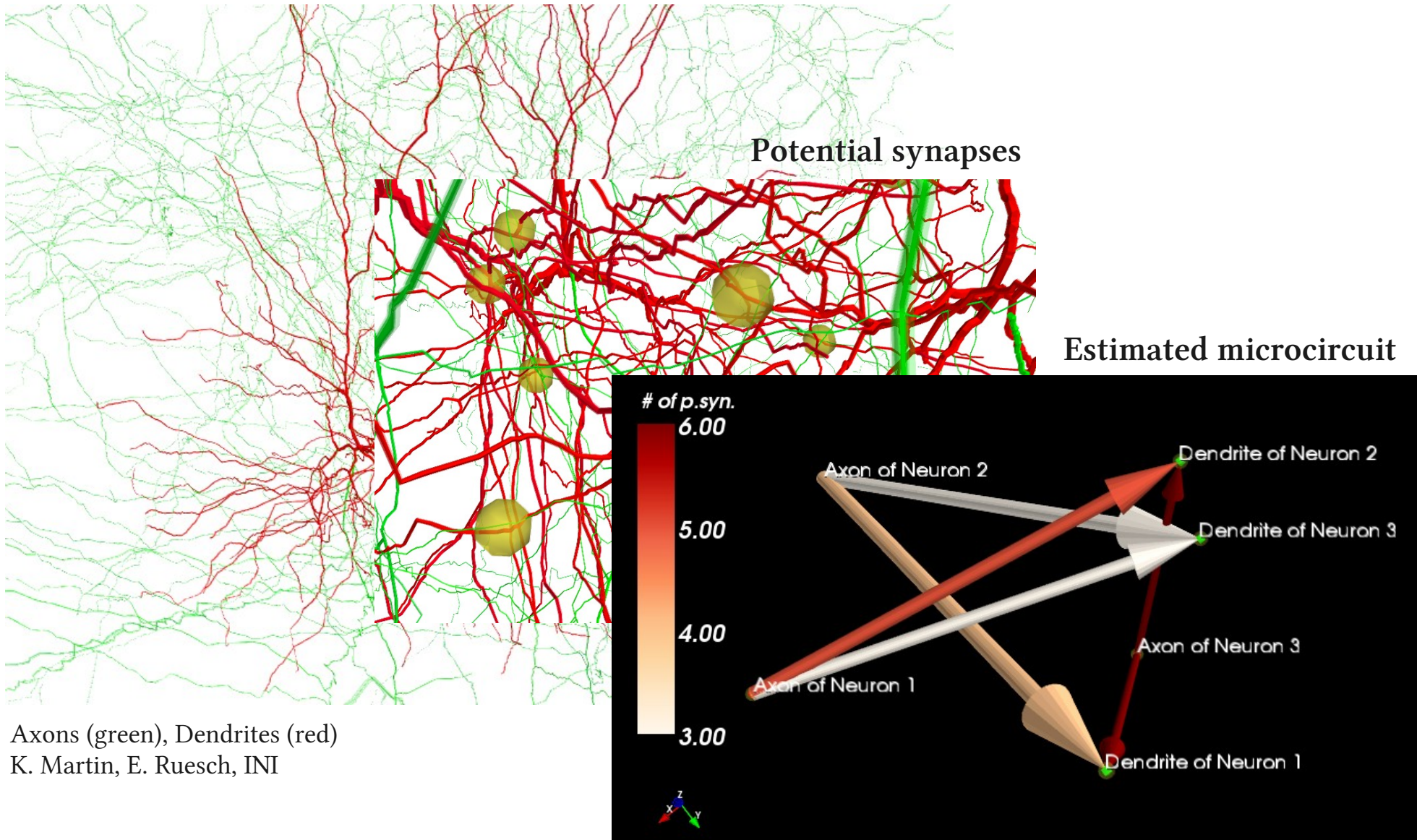
ConnectomeViewer was applied to *mesoscale* connectomes

- for analysis of data and
- visualization of the results

Neuron reconstructions in cat visual cortex

The cellular level

Three Layer 2/3 pyramidal neurons



Conclusion

Connectome File Format applicable on the cellular level

ConnectomeViewer was applied to a *microscale* connectome

- for estimation of a cortical microcircuit and
- visualization of the neurons and the microcircuit

Outlook

ConnectomeViewer

Improve brain connectivity measures
(modularity, hub classifications, motifs)

Improve visualization
(better network layouting)

ConnectomeWiki

Motivate people to contribute
Enter data from the literature

Building ConnectomeDatabase

Repository of Connectome Files

Human Connectome Project

(NIH funded, \$6 mio, 2010 - 2015)

Connectomics

Critical remarks

Dimensionality

Information in at least 3 dimensions

More parameters (e.g. # of vesicles, spine shapes, molecular subtype of neuron etc.)

Variability

Neuronal shape and connectivity differ between individuals

Fine details of shape vary a lot

Stability

Connectomes change with maturation, aging, experience

Others

The cost is not worth the putative benefit.

We have the *C.elegans* connectome, however we do not know how the worm works

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Patricia Milz, Roberto Pascual-Marqui

Open Source Community

All the Python, SciPy, Semantic Mediawiki developers.
Prabhu Ramachandran and Gael Varoquaux (Mayavi), Enthought
Benjamin Thyreau, Danny Holten

Connectomics

Spread the news

ConnectomeViewer

Download, Datasets, Documentation, Developer Zone

<http://connectomeviewer.org>

ConnectomeWiki

<http://connectome.ch/wiki/>

