Workshop

Connectivity in the Brain

June 4, 2008

Max-Planck-Institute for Human Cognitive and Brain Sciences, Stephanstrasse 1a, Leipzig
(Wilhelm-Wundt-Room)

In recent years, connectivity has been recognized as a major determinant of brain function. The notion of connectivity encompasses physical connectedness between brain areas and structures (structural connectivity), correlations between activations of different brain areas (functional connectivity), and the influence one area exerts over another (causality, effective connectivity). The methodology to detect and quantify these types of connectivity has made substantial progress in the last couple of years. This one-day workshop aims at familiarizing the participants with some of the key approaches, and offering a discussion platform for the advantages and drawbacks of the different concepts.

The workshop is open to all interested scientists, no registration is necessary.

Introduction

09:00 – 09:15
Thomas Knösche

Keynote Lecture

09:15 – 10:15
Almut Schüz (MPI Tübingen) *Quantitative Neuroanatomy as a Key to Cortical Function*

10:15 – 10:30
Coffee Break

Session 1

Fiber Anatomy Revealed by Diffusion Weighted MR Images

10:30 – 11:15
D. Jones (Cardiff) *How do we measure 'connectivity' with diffusion MRI*

11:15 – 12:00
M. Descoteaux (Paris) *Reconstruction of Fiber Orientation Density from High Angular Resolution Diffusion Imaging (HARDI) Data*

12:00 – 12:45
A. Anwander (Leipzig) *Cortex Parcellation Based on dwMRI – Results and Perspectives*

12:45 – 13:45
Lunch Break (Lunch provided)

Session 2

Connectivity Estimates based on EEG, MEG and fMRI

Speakers:

13:45 – 14:30
S. Kiebel (London) *Dynamic Causal Modelling: Network models for fMRI and M/EEG*

14:30 – 15:15
O. David (Grenoble) *Can fMRI be used to identify neural drivers? Insights from a rat model of absence epilepsy.*

15:15 – 15:30
Coffee Break

15:30 – 16:15
T.R. Knösche (Leipzig) *Dynamic Properties of Neural Mass Models*

Concluding Lecture

16:15 – 17:00
M. Tittgemeyer (Köln) *Towards an Integrated Analysis of Anatomical and Functional Connectivity*

Abstracts and CVs

Almut Schüz
Quantitative Neuroanatomy as a Key to Cortical Function

Abstract
In this talk I will summarize many years of work in our laboratory on the basic structure of the cerebral cortex. I will present quantitative data on the composition of the grey matter, as well as data on the rich connectivity of the cortex with itself via the white matter. The data are derived from conventional histological studies, as well as tracer studies in the mouse cortex, and from a study on the human cortical white matter on the number and thickness of fibres in the long-range bundles of the white matter.
The main emphasis of this talk will be on the question what quantitative neuroanatomy can tell about the network structure of the cortex and what conclusions one can draw on cortical function. The data may also help to interpret connectivity studies in the living brain.

CV
Since 1980, Almut Schüz is a staff scientist at the Max Planck Institute for Biological Cybernetics in Tübingen where she is leader of the Laboratory of Neuroanatomy. In 1975 she finished her Diploma in Biology at the University of Tübingen and made then her PhD in the group of Valentino Braitenberg at the MPI for Biological Cybernetics. In 1983 and 1991 she has been a guest researcher at the University of St. Petersburg, Russia, and in 1998 Fellow at the Institute for Advanced Studies in Delmenhorst, Germany. Since 1997 she is also apl. Prof. at the University of Tübingen. Her research deals with the investigation of brain structures, with the aim to relate brain structures to brain functions (learning, representation of concepts, orientation selectivity etc.). Her main focus is on the structure of the cerebral cortex. Much of her work is summarized in her book together with Valentino Braitenberg "Cortex: Statistics and Geometry of Neuronal Connectivity", Springer (1998).

D. Jones
How do we measure 'connectivity' with diffusion MRI

Abstract
In this talk, I will review some of the basic strategies for using diffusion MRI data to make maps of white matter pathways and their connections. I will then focus on the interpretations of these maps and their use, thinking carefully about the definition of 'probabilistic', 'connectivity' and 'likelihood' of connection – and the sorts of hypotheses / inferences that may be made with such information. Importantly, we will also consider what information is also thrown away. This will highlight certain shortcomings in extant mehtods, and – although I won't have the answers, the aim is to open up a general discussion about the pros and cons and various methods and what we may be missing.

CV
Derek Jones obtained a first degree in physics at the University of Nottingham, before training as a medical physicist in radiotherapy and nuclear medicine. He then completed a PhD in diffusion tensor imaging in 1998, before taking up post-doc positions at the Institute of Psychiatry, London and National Institutes of Health, Maryland, USA. He then became a Wellcome Trust Advanced Fellow at the Institute of Psychiatry in London, and 2 years ago moved to Cardiff University Brain Research Imaging Centre (CUBRIC), in Cardiff, Wales to take up a personal Chair and Directorship of MRI.

M. Descoteaux

Reconstruction of Fiber Orientation Density from High Angular Resolution Diffusion Imaging (HARDI) Data

Abstract

At the current resolution of diffusion-weighted (DW) magnetic resonance imaging (MRI), research groups agree that there are between one third to two thirds of imaging voxels in the human brain white matter that contain multiple fiber bundles crossing. This presentation tackles the important problem of recovering crossing fiber bundles from high angular resolution diffusion imaging (HARDI) data. The main goal is to overcome the limitations of diffusion tensor imaging (DTI). It is well-known that imaging voxels where there are multiple fiber crossings are locations where DTI is limited and inadequate. We first review some of the latest q-space imaging and HARDI techniques able to recover complex fiber orientation distributions. In particular, a simple, fast and robust Q-ball imaging (QBI) reconstruction is presented using spherical harmonics. QBI is a recent HARDI technique that reconstructs the orientation distribution function (ODF) of the average diffusion of the water molecules in the underlying fiber population. It is able to describe multiple fiber populations crossing. From this diffusion ODF, we describe how we can reconstruct the fiber ODF in order to perform accurate tractography. We introduce a new spherical deconvolution sharpening method that transforms the diffusion ODF into a fiber ODF. Therefore, this presentation clarifies the relationship between the diffusion signal, diffusion ODF and fibre ODF.

CV

Maxime Descoteaux received the BSc and MSc degrees in mathematics and computer science from McGill University in Canada in 2002 and 2004, respectively, and the PhD degree in computer science in 2008 from Université de Nice—Sophia Antipolis in France, all with highest honors. He is currently a postdoctoral fellow at Neurospin / CEA in Paris, France. His research interests are in medical image analysis, brain imaging and computer vision, with a special interest on the acquisition and processing of diffusion MRI data to infer the white matter architecture of the brain and to better understand functional coupling between cortical regions of the brain. To find out more about his research and some selected publications take a look at http://www-sop.inria.fr/odyssee/team/Maxime.Descoteaux/index.en.html.

O. David

Can fMRI be used to identify neural drivers? Insights from a rat model of absence epilepsy.

Abstract

Whether functional (fMRI) permits to identify neural drivers remains an open question of particular importance to refine neuropsychological models. In a rat model of absence epilepsy showing spike-and-wave discharges (SWDs) originating from the first somatosensory cortex (S1BF), we performed simultaneous electroencephalographic (EEG) and fMRI measurements, and subsequent intracerebral EEG (iEEG) recordings in regions strongly activated in fMRI (S1BF, thalamus and striatum). FMRI connectivity was determined using multivariate autoregressive modelling of fMRI signals (GCM – Granger Causality Maps), and using a model relating synaptic activity to fMRI (DCM - Dynamic Causal Modelling). Directed functional coupling was estimated from iEEG using the asymmetry in generalised synchronisation metrics. The neural driver of SWDs was estimated in S1BF only from iEEG and from DCM. GCM connectivity was biased by the heterogeneity of brain hemodynamics. This talk will provide the first empirical substantiation of the theoretical

possibility to improve fMRI coupling estimation from hidden neural states and will provide an empirical validation of the raison d'être for DCM.

CV

Dr. Olivier David graduated in applied physics from Ecole Normale Supérieure in 1999 and is an expert of functional neuroimaging and electrophysiology. He was trained in fMRI (1998-1999, Inserm U438 Bioclinics NMR, Grenoble, supervised by C. Segebarth), MEG/EEG source localisation and neurodynamics (1999-2002, Lena CNRS UPR640 Cognitive Neuroscience and Brain Imaging, Paris, supervised by L. Garnero & F. Varela), and MEG/EEG neural modelling (2002-2004, Functional Imaging Laboratory, London, supervised by K. Friston). In 2005, he obtained a permanent researcher position to coordinate an EEG/fMRI program in humans and rodents at the Inserm U836 Grenoble Institute of Neuroscience, France. The main focus of his current research is to understand the effects of brain electrical stimulation on the organisation of functional networks using fMRI, intracerebral EEG and neural modelling.

S. Kiebel

Dynamic Causal Modelling: Network models for fMRI and M/EEG

Abstract

Dynamic Causal Modelling (DCM) is an approach first introduced for the analysis of functional magnetic resonance imaging (fMRI) to quantify effective connectivity between brain areas. Recently, this framework has been extended and established in the magneto/ encephalography (M/EEG) domain. DCM for M/EEG entails the inversion a full spatiotemporal model of evoked responses, over multiple conditions. This model rests on a biophysical and neurobiological generative model for electrophysiological data. A generative model is a prescription of how data are generated. The inversion of a DCM provides conditional densities on the model parameters and on the model itself. These densities enable one to answer key questions about the underlying system. A DCM comprises two parts; one part describes the dynamics within and among neuronal sources, and the second describes how source dynamics generate data in the sensors, using the lead-field. The parameters of this spatiotemporal model are estimated using a single (iterative) Bayesian procedure. This talk will motivate and describe the current DCM framework. Two examples show how the approach can be applied to M/EEG experiments.

CV

Dr. Stefan Kiebel obtained his PhD in 2001 from the University Magdeburg in Germany. Since 1999 he has been a member of the methods and theory group of the Functional Imaging Laboratory, University College London, UK. During his time in London, he developed methods for improved analysis of functional magnetic resonance imaging (fMRI) data ('Anatomically informed basis functions'). Since 2003 he has been mainly working on modelling and analysis of magneto/encephalography (M/EEG) data. He is one the main developers of the analysis software 'Statistical Parametric Mapping', which is widely used for analysis of brain imaging data. Currently, he is pursuing two main interests: The first is modelling M/EEG data with Dynamic Causal Modelling and other Bayesian techniques. The second is theoretical modelling of global brain function using dynamic, hierarchical, nonlinear systems.

Marc Tittgemeyer

Towards an Integrated Analysis of Anatomical and Functional Connectivity

Abstract
It is a well establishes principle in functional neuroanatomy that function of a brain region is constraint by its connections. In fact, it has been widely argued on the basis of macaque literature that each cortical area has a unique pattern of cortico-cortical connections--a 'connectional fingerprint'. In-vivo access to connectional information, using diffusion tractography has therefore provided great potential for identifying functional subunits. Indeed, independent fMRI data have already shown close correspondence between connectionally and functionally defined subunits in a couple studies. In this talk, I will review some basic approaches for study designs where functional MRI data and diffusion MRI data can be complementary in understanding connectivity in the brain, and I will discuss an approach to integration information on anatomical connectivity derived by diffusion tractography in the modeling of effective connectivity between brain areas.

CV
Marc Tittgemeyer obtained a degree in geophysics at the University of Karlsruhe, before he completed his PhD in physics in 1999. He has been guest scientist at the Russian Academy of Science, the University of Edinburgh and the Spanish Research Foundation (CSIC) in Barcelona, before he was taking up post-doc position at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig in the Department of Neurology. There he was for 5 years concerned with MRI- based morphometry, before he moved to the Max Planck Institute for neurological Research in Cologne taking over a staff scientist position and heading the cortical networks research group.