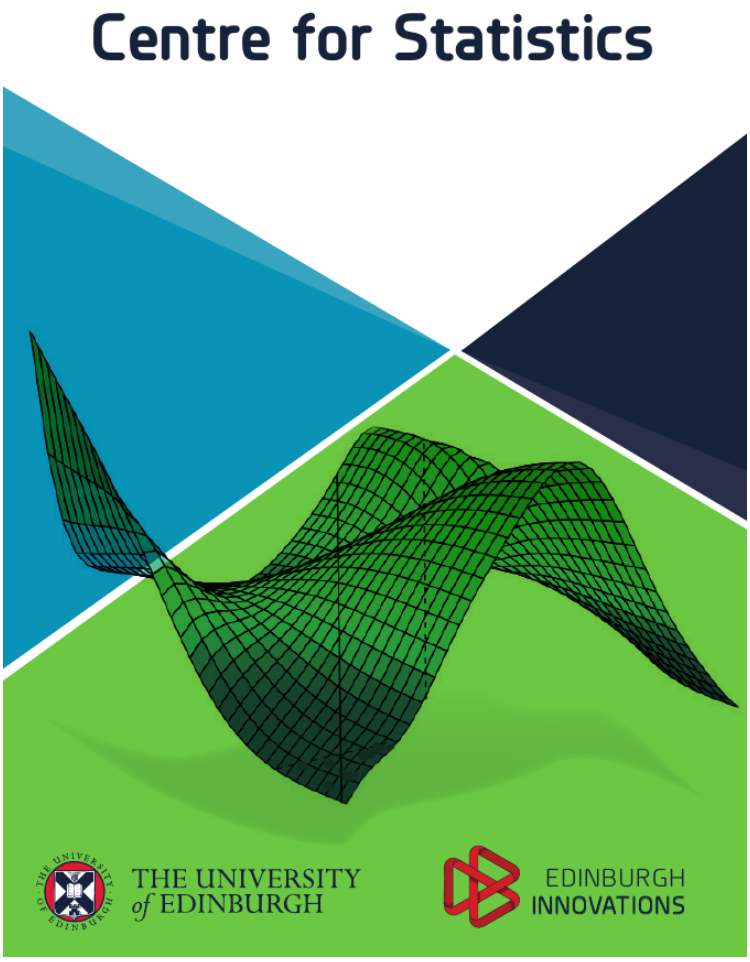
Joint Research Day

Center for Statistics—Center for Discovery Brain Sciences



The Centre for Statistics (CfS) unites data-driven researchers from across the University of Edinburgh and associated institutions, thereby building the capacity needed to address key scientific and societal challenges. The CfS aims to deepen mutual understanding between statisticians working in the mathematical sciences and researchers in other disciplines, leading both to cutting-edge interdisciplinary research that utilises modern statistical tools, and to innovations in statistical research.

The CfS promotes an environment which fosters interdisciplinary research and knowledge exchange by:

- *The organisation of interdisciplinary seminars and discussion series based in academic units across the University, and through the provision of small grants to aid the development of collaborative research proposals.*
- *Inviting world leading statisticians on extended research visits where they spend time in academic units across Scotland.*
- *Promoting the application of the statistical sciences by holding an annual conference showcasing the most innovative interdisciplinary research and applications and organising an annual David Finney Lecture on Statistical Research and its Benefits to Society.*
- *Establishing new connections between mathematics and other academic areas, and with industrial, governmental and commercial users. The CfS has founded Statistical Consultancy Unit which acts as an interface between external clients and the expertise within the CfS.*
- *Being at the forefront of training the next generation of statisticians and data scientists.*

Programme

- **11.45–12.15** Welcome lunch
- **12.15–12.45** **Prof Jonathan Gair** (CfS)
- **12.45–13.15** **Prof Ian Duguid** (CfDBS)
- **13.15–13.45** Discussion
- **13.50–14.00** **Prof David Price** (CfDBS)
- **14.00–14.10** **Dr Ioannis Papastathopoulos** (CfS)
- **14.10–14.20** **Dr Nathalie Rochefort** (CfDBS)
- **14.20–14.30** **Mr Nicolo Margaritella** (CfS)
- **14.30–15.00** Discussion
- **15.00–15.30** Tea and coffee break
- **15.30–16.00** **Dr Miguel de Carvalho** (CfS)
- **16.00–16.30** **Prof Matthew Nolan** (CfDBS)
- **16.30–17.00** Discussion and information about seed funding

Abstracts (in order of appearance)

Inference using emulation of computationally intensive models

Speaker: Jonathan Gair
Abstract: Due to continual increases in computational power, it has become possible to simulate complex physical and biological processes on computers. It is natural to want to use such simulations to make inferences about the parameters characterising the physical or biological process using observed data. Unfortunately, inference typically requires the evaluation of the model at thousands of points in the parameter space, which is impractical for the most complete computational models that are very expensive to evaluate. One approach to overcome this problem is to construct a statistical emulator of the model, which takes a small number of input simulations and interpolates between them to cheaply generate both a best guess output value and an uncertainty at arbitrary points in parameter space. In this talk I will describe one approach to constructing such emulators, using Gaussian process regression. I will illustrate the method with an application to environmental science, by emulating the NIRAMS model of nitrate pollution in ground water in Scotland, but the focus will be on the methodology which can be applied to many different problems in a wide range of application areas.

Neural circuit dynamics underpinning behaviour

Speaker: Ian Duguid
Abstract: Neural circuits in the brain integrate large volumes of information to generate complex patterns of output that shape ongoing behaviour. Understanding how individual patterns of neural activity causally relate to behaviour is a necessary prerequisite to understanding the function of the brain. Although recent advances in in vivo recording methods has enabled scientists to investigate neural circuit function at unprecedented spatiotemporal resolution, this has generated an additional challenge: how to mine complex, high dimensional datasets to extract general principles of neural circuit function. In this talk, I will discuss our efforts to map circuit computations to behaviour, the methods we employ and resulting data analysis challenges.

Developmental mechanisms involved in the production of cerebral cortical neurons

Speaker: David Price
Abstract: Cerebral cortex contains nerve cells that are either excitatory or inhibitory. Cortex makes its own excitatory cells but acquires inhibitory cells from elsewhere. I am asking how and why cortex is restricted to making only excitatory cells. I propose that cortical cells are protected against the influence of signals around them that could induce them to make inhibitory cells because if cortex were to make its own inhibitory cells they would have incorrect properties. I am using sequencing and other methods to test the following predictions: (i) removal of protection renders genomic elements regulating genes that specify inhibitory cells activatable; (ii) cortical cells released from protection can be reprogrammed by signals capable of inducing inhibitory cell production; (iii) if cortex is allowed to make inhibitory cells, they will have abnormal properties. The research will help explain mechanisms stabilizing the fates of cortical cells in the rapidly changing environment of the developing brain.

Grid field intensity and random fields

Speaker: Ioannis Papastathopoulos
Abstract: A grid cell is a type of neuron in the brains of many species that allows them to understand their position in space. In a typical experimental study, an electrode capable of recording the activity of an individual neuron is implanted in the cerebral cortex of a mouse, in a section called the dorsomedial entorhinal cortex, and recordings are made as the rat moves around freely in an open arena. In this talk I will present current work on building a statistical modelling framework for estimating grid field intensity from electrophysiological data. The statistical model is of marked point process nature and is designed to facilitate flexible extensions to situations where modelling firing intensity in not the primary statistic of interest, but plays a key role in understanding the variation of concomitant variables such as head-direction.

Correlating activity of neuronal circuits with behavior

Speaker: Natalie Rochefort
Abstract: My lab investigates how brain visual areas process visual information and how this process relates to an animal's behavior. We apply an imaging method, two-photon calcium imaging, to monitor neuronal population activity in the brain of awake behaving animals. By simultaneously recording neural activity and parameters of animal's behavior, we can assess how behavioural context modulates neural activity.

While remarkable recent experimental breakthroughs have been done in the field of in vivo imaging, the next big challenge is an analytical one: how to develop the analytical techniques that can use these data to model, dissect and understand the complex interactions between neural activity, behaviour and task variables. The main difficulty lies in the different statistics of the elements that need to be modelled: some being discrete such as licking or presented visual stimuli while others such as running speed, pupil size and calcium signals are continuous. I will present examples of such data sets and highlight the challenges for analysis and modelling of these results.

Parameters clustering in Bayesian functional PCA of neuroscientific data

Speaker: Nicoló Margaritella
Abstract: The modelling of brain activity has a long history but only in recent years has it started benefiting from the extraordinary technological advances in the fields of neurophysiology and neuroimaging. With a remarkable amount of spatiotemporal data recordable simultaneously from several parts of the brain, researchers are challenged to find models that can capture meaningful patterns and structures behind such complexity. Thus motivated, we aim at modelling neuroscientific data employing functional data analysis (FDA) within a Bayesian perspective; in particular, we exploit the flexibility of an infinite mixture model for clustering functional principal component scores to account for curve dependencies. We show that clustering of parameters in functional Principal Component Analysis (PCA) can be easily expressed in terms of a hierarchical model and offers a general approach of time series clustering with further insights into curves classification. Moreover, results from a simulation study show improvements in curves and correlation reconstruction especially with low signal-to-noise ratio.

Discrimination surfaces with application to region-specific brain asymmetry analysis

Speaker: Miguel de Carvalho

Abstract: In this talk, I will introduce discrimination surfaces as a diagnostic tool for localizing brain regions where discrimination between diseased and non-diseased subjects is higher. To estimate discrimination surfaces, I will introduce a Mann–Whitney type of statistic for random fields, and present large-sample results characterizing its asymptotic behaviour. Simulation results demonstrate that our estimator accurately recovers the true surface and corresponding interval of maximal discrimination. The empirical analysis suggests that in the anterior region of the brain, schizophrenia patients tend to present lower local asymmetry scores in comparison to subjects in the control group.

Joint work with G. Martos.

Spatial and temporal analysis of neural circuits

Speaker: Matthew Nolan

Abstract: Circuits in the brain are organised across spatial and temporal scales covering several orders of magnitude. Rapid technological progress is enabling experimenters to investigate neural circuit dynamics operating at timescales from milliseconds to days and beyond, and neural circuit organisation at spatial scales from brain areas that span several cubic millimetres to molecular interactions at the scale of nanometers. I will highlight research questions and datasets that span these scales and that pose challenges and opportunities for future data analysis and development of novel theories for brain function.

Participants

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