basque center for applied mathematics

EXCELENCIA SEVERO OCHOA

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Courses 2014-15

April 9, 23 and 30, 09:30 -11.30 h (3 sessions) 15:00-18:00 (9 hours)

BCAM Mazarredo 14, 48009 Bilbao, Basque Country, Spain www.bcamath.org

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MATHEMATICS AND BRAIN

The brain is a fascinating, remote and complex organ that cannot be easily access directly without disturbing its functions in a major way. An immediate corollary of this observation is that brain studies rely on indirect, often sparse and noisy observation, and mathematical models provide the context for interpreting and analyzing empirical data.

In this series of lectures we will look at different aspects of the brain and present an overview of the mathematics required to understand them and predict how the brain would behave under a variety of conditions. In particular, we will look at the brain from different points of view. In particular, we will focus on:

- Brain metabolism and the mathematical models that in the past two decades have been used extensively to understand the biochemistry behind brain activity, both during excitation and inhibition. The multi-scale nature of the problem, complexity of governing equations and difficulty in assigning suitable values to the model parameters will be discussed.

- Brain Positron Emission Tomography (PET) is often employed to measure brain metabolism. The mathematics behind PET involves probabilistic models and the solution of two inverse problems. The mathematical challenges in recovering brain activity from PET measurements will be outlined.

- Brain electrophysiology, with particular emphasis on the magnetic field following the concerted firing of a group of neurons. The inverse problem of identifying the brain region whose activation triggered the magnetic field measured outside the skull with magneto-encephalography (MEG) devices will be presented and the many challenges associated with its solution will be presented.

- Brain hemodynamics, and its key role in assuring a continuous delivery to brain tissue of important metabolites, e.g., glucose and oxygen, and the prompt removal of byproducts of metabolism, e.g., carbon dioxide. The physiological and mathematical assumptions behind BOLD fMRI studies will be discussed.

The connections and integration of these different brain functions will be emphasized throughout, and many open question on the problem on inferring about a type of brain function from the observation or simulation of another one will be discussed.

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- Olliger JM and Fessler JA (1998) Position emission tomography IEEE Sig. Proc. Mag., 14(1):43-55.
- Buxton RB, Wong E and Frank LR (1998) Dynamics of Blood Flow and Oxygenation Changes During Brain Activation: The Balloon Model. MRM 39:855-864.
- A fun webpage: <A HREF="http://web.eecs.umich.edu/~fessler/result/tr/pet,trans,2d,sino/">here</A>
- Hämäläinen M, Hari R, Ilmoniemi RJ, Knuutila J and Lounasmaa OV (1993).
- Magnetoencephalography-theory, instrumentation, and applications to non-invasive studies of the working human brain. Reviews of Modern Physics, 65(2), 413.