PREFERENCE: POSTER PRESENTATION

Theoretical Neuroanatomy: Scaling in Cortical Area Connectedness

Jan Karbowski

Division of Biology, California Institute of Technology,
Pasadena, CA 91125, USA

Email:

Abstract:
Functioning of the cerebral cortex depends on the intricate pattern of connections between cortical areas. However, our knowledge of such pattern is still obscure for many mammals. Here, mathematical formulas are presented which describe macroscopic cortical connectivity in terms of other cortical parameters, e.g. axonal length in white matter, module size, and number of areas. These formulas are discussed primarily in the context of data for monkey and cat, but it is argued that they can also have predictive power for other, less studied, species due to known scaling relations among cortical parameters.

PREFERENCE: POSTER PRESENTATION

Cerebral cortex has evolved to enhance its computational capacity and cortical wiring clearly plays a major role in this process. Although there are known detailed studies of axonal wiring on the microscopic scale (within local circuits), connectivity on the macroscopic scale is known only for few species. One of the reasons of this lack of data
is experimental difficulty, another reason is confusion with precise identification of “real” cortical areas.

The purpose of this study is to present theoretical formulas which, in principle, can provide an information about connectivity between areas in less neuroanatomically studied mammals. This is possible by relating cortical area connectedness to other cortical parameters for which there are known scaling laws with the brain size. In this way, the connectivity formulas can have predictive power which can inspire further experimental work in this direction.

In order to derive a formula for connectivity between areas it is useful to divide them into modules. Each module represents a local group of neurons with similar functional properties that is capable of sending at least one macroscopic bundle of long-range axons to a particular place in the cortex via white matter. One can think about such defined modules as being cortical columns or barrels that have been found in the visual and somato-sensory cortices of different mammals. Using similar arguments as in [1], it can be shown that a probability of connection between two areas *i* and *j* is given by

$$Q_{ij} = 1 - \exp(- W_i\, p_{ij} / \square\text{^}2),$$

where W_i is surface area of cortical area *i*, $\square$ is average linear module size, and p_{ij} is probability of connection a module in area *i* to the area *j*. The latter probability depends in a simple manner on average length of axons in white matter, total cortical surface area, number of areas in a class to which belongs area *j*, and few other free parameters.

Using data on monkey and cat contained in a series of papers by Young et al [2, 3, 4] one can determine free parameters present in probability p_{ij}. If we assume that these
parameters do not change much from species to species, then one can say something
about cortical area connectedness for other species. This can be done by using known scaling laws with brain size for other parameters contained in probabilities Q_{ij}. This is the first such approach, however its precision would have to be tested by more neuroanatomical studies.

Alternatively, one can reverse the course of action and to try to determine the average axon length in white matter given knowledge about distribution of probabilities Q_{ij}. This is also an interesting problem, since still it is not known e.g. how precisely white matter axon length scales with the brain size.

References:

[1] J. Karbowski – manuscript submitted to *Neural Computation*

[2] J.W. Scannell, M.P. Young, and C. Blakemore, *J. Neurosci. 15, 1463 (1995).*

[3] M.P. Young, *Proc. Roy. Soc. B 252, 13 (1993).*

[4] M.P. Young, J.W. Scannell, and G. Burns, *The Analysis of Cortical Connectivity,* Austin, TX, Landes (1995).