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Complex Brain Networks

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Introduction

In this work we are interested in perhaps nature's most complex system, the mammalian cerebral cortex [1]. Recent advances in experimental neuroscience allow, for the first time, noninvasive studies of white matter tracts in the human nervous system, thus making available cutting-edge anatomical data describing these global connectivity patterns. Further, contemporary "proof of principle" work has shown that existing biological knowledge can be recovered from this connectivity data [2], and we are now in a position to make new discoveries. This work has two main aims: (i) a novel analysis of cutting edge anatomical connectivity data from the brain using a network science approach, and (ii) the development of a new, computable measure of connectivity for a weighted network.

Results

We present a comparison of connectivity data for stroke patients and normal control subjects. Using a spectral reordering algorithm we are able to clearly identify a clustering of this new data into two distinct groups – stroke patients and controls. We also introduce the idea of *communicability* of a network [3]. In many real-world networks information can disseminate along non-shortest paths, and since communicability is typically considered to be the shortest path between pairs of nodes, important information on the communicability of the network can be missed. By accounting not only for the shortest path between two nodes but also all other intermediary paths, the measure presented in [3] provides a more robust description of network communicability. Figure 1 shows a plot of the average communicability for both stroke patients and controls; it can clearly be seen that on average there is a reduction in the communicability for stroke patients with respect to the control subjects. Furthermore, post processing of the data allows us to identify which brain regions are most affected enabling us to draw important biological conclusions.

One drawback of this generalisation of communicability is that it requires the adjacency matrix of the network to be binary; this has several disadvantages for weighted networks, for example, the requirement for an often arbitrary cut-off level in order to discretise the matrix. It is thus highly desirable to extend these ideas to weighted networks. Here we discuss some recent work that has the goal of providing such an extension and illustrate its potential usefulness by answering biologically relevant questions such as "can certain brain diseases be identified with local or global changes in network communicability?"

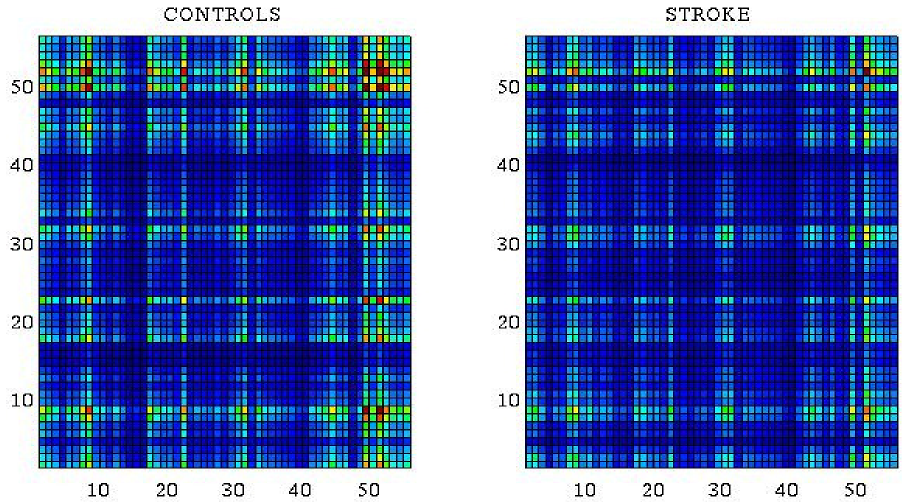

FIG. 1 (colour online): A plot of the average communicability for both controls and stroke patients. Each pixel represents the communicability between different brain regions and is coloured using a heat map; low (high) temperatures represent low (high) communicability respectively.

Discussion

Due to modern noninvasive experimental neuroscience techniques cutting-edge brain anatomical data has recently become available. Our aim here is to present a first step towards understanding this data using complex network reasoning. Since the resulting networks are naturally weighted we argue against the discretisation of the corresponding adjacency matrices, preferring instead to extend current network tools to the case of nonnegative weighted networks. Here we report on the success of a "weighted network communicability measure" as a means to distinguish local and global differences between diseased patients and controls.

References

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