ABSTRACT

Non-random connectivity has repeatedly been reported in cortical networks, yet underlying connection principles remain elusive. Proposing an abstract geometric network model reflecting stereotypical axonal and dendritic morphology of local cortical layer 5 networks, we here investigate in how far anisotropy in connectivity can constitute such an underlying connectivity rule. Using a combination of analytical and numerical analysis, we find that while standard network measures and pair connectivity remain unaffected, higher order connectivity is strongly influenced by anisotropy, in many cases reflecting connectivity patterns found in local circuits. Presenting a network model inherently featuring beyond distance-dependcy, the results shown here not only but

1 INTRODUCTION

Brain network connectivity, the description of links between the brain's computational units, lies at the heart of many theories trying to explain the exceptionally varied and robust functionality of the brain. As an essential component in the investigation of the emergence of its unique cognitive abilities, brain connectivity is associated with memory and the performance of many tasks. Connectivity is, in its essence, a purely abstract concept and is thus intimately tied to mathematical theories. Providing the concepts mathematical concept spur reaserach in brain,borrowing many of the existenting to research.

In the field of theoretical and computational neuroscience neural network models are studied as of brain networks. Studies interested in the dynamical aspect for example investigate . The standard model for such simulations is that of random graph (Brunel 2000). However, results over the last years show that local cortical circuits display highly non-random connectivity features (Song et al. 2005; Perin et al. 2011). It is unclear how to incorporate such as underlying remain yet to be identified. unclear how to incorporate. Important to identify underlying rules.

The search underlying principles has since (Klinshov et al. 2014). In an effort to contribute to this discussion, we here investigate anisotropy in connectivity. Motivated from observations of stereotypical morphology, the may not only provide but further can be a first step towards network models.

1.1 OVERVIEW

Following the introduction and this outline, a short overview of the biological terms frequently appearing throughout this text is given as reference in Section 1.2. The central mathematical objects in this study, various directed graph models, are then introduced and discussed in detail in Chapter ??. Building on these concepts, Chapter ?? introduces the anisotropic network model as the main object of investigation in this thesis. Next to an in-depth introduction of anisotropic connectivity concept, the chapter also includes, laying the groundwork for the analysis of structural features in anisotropic networks in Chapter **??** and **??** then

1.2 BIOLOGY OF NEURAL NETWORKS

The fundamental computational units in brain networks are neurons, electrically excitable cellular elements that process and transmit information by a cell type dependent regime of electrical and chemical signals. Neurons are linked through synapses, forming together an expansive, interconnected network of different neuron types, dividing into functionally and anatomically distinct areas. The number of neurons in the average human brain is estimated at about 86 billion, connected by 10^{14} - 5×10^{15} synapses (Herculano-Houzel 2009; Drachman 2005). Among the different brain areas studied, the multilayered cerebral cortex stands out as a region of particular interest with many studies analyzing its structural and dynamical features.

The principal excitatory neuron type in cortical networks are pyramidal cells. Connection between those neurons are mainly of chemical nature, in the synaptic contacts between cells the release and consequent reception of neurotransmitters transmits electrical signals. While cortical networks are considered sparse, pyramidal cells typically receive tens of thousands excitatory and several thousand inhibitory inputs, making up for an overall connectivity of about 10% in local networks (Spruston 2009). Such synaptic contacts are inherently asymmetric; signals travel from the cell body of a neuron along the axon to be transmitted at a synapse contacting the dendritic tree of the post-synaptic neuron. Morphology of axon and dendrite are characteristically different; it is this difference that is taken up in this study and serves as a basis for the network model introduced in Chapter **??**.

To enable we introduce For Brain networks . They are well presented by the mathematical object of a directed graph, which will be discussed in detail in the following chapter.