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Computational tools for assessing the properties of 2D neural cell cultures

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Neurons cultured in vitro provide a particularly promising experimental system for the analysis of properties, such as information coding, transmission, and learning, that are conventionally associated with biological neural networks. In these systems, isolated cells are placed on top of a recording plate (microelectrode array, MEA), where they spontaneously develop a random connectivity structure. Typical cultures consist of several thousands of neurons and the connectivity density varies from very low at the beginning of an experimental trial to high in mature cultures. In the absence of external stimuli, a culture exhibits a typical pattern of spontaneous activity, alternating intervals of slow spiking and bursting with the transition intervals of increasing activity. Spontaneous activity recorded in the cultures of rat cortical cells is described in [1,2] and an explanation of the phenomena is proposed in [3]. The behavior in the presence of external stimuli is also reported in the literature, for example, the adaptation exhibited in the presence of frequent and rare stimuli is assessed experimentally and through a computational model in [4]. The present work is related to the previously reported study [3] in which an image-processing algorithm is used to detect some structural parameters of cell cultures. A typical result from this study is illustrated in Figure 1. The original image of cultured cells on top of recording plate is shown in panel A, one of its segments in B, and the result of the applied algorithm in C. The blue pattern on panel C corresponds to cells. This approach, in general, enables automated estimation of parameters like the number of cells, or the average density of connections between the cells. Here, we propose a computational model based on the study in [3]. The neural network model is composed of leaky integrate-and-fire neurons, connected in a recurrent network as shown in panel D. The network is fed with the quantitative information about the structure of the cell cultures. Such model, although approximate, captures well the essential properties of the topologies observed in cultures. The presented model is used to reproduce and analyze network behavior observed in the absence of external stimuli. The structural parameters are estimated in different phases of development to closely relate them to the observed behavior. The relation between the network topology and behavior is systematically examined throughout this study.

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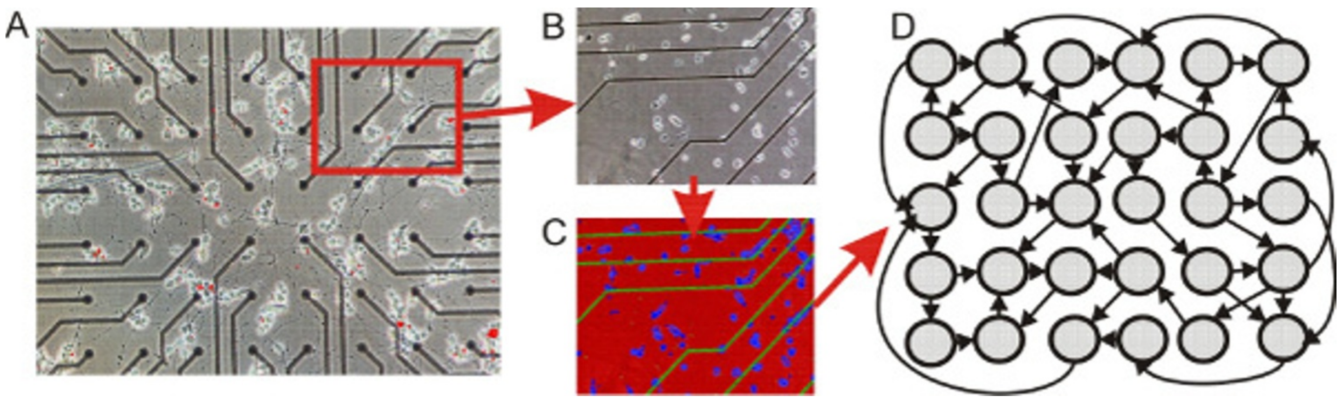

Figure 1
From cell cultures to models of neural networks. The technique for pattern recognition from images of cell cultures (reported in [1]) is used to assess the structural parameters incorporated in the computational model.