On the Computational Power of Neural Microcircuit Models: Pointers to the Literature

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Abstract. This paper provides references for my invited talk on the computational power of neural microcircuit models.

Biological neural microcircuits are highly recurrent and consist of heterogeneous types of neurons and synapses, which are each endowed with an individual complex dynamics [4], [6], [3], [7], [8], [23], [20]. Hence neural microcircuits are as different as one can imagine from the familiar boolean circuits in our current generation of computers, but also very different from common artificial neural network models. This has given rise to the question how neural microcircuits can be used for purposeful computations.

There are two quite different ways of approaching this question. One way is to construct circuits consisting of biologically realistic components that can simulate other models for general-purpose computers such as Turing machines [13] or general-purpose artificial neural network models [14], [16], or to construct circuits that carry out specific computations such as for example simpified speech recognition [10]. Another way, which is discussed in my talk, is to recruit – with the help of suitable adaptive mechanisms – biologically realistic "found" or emerging models for neural microcircuits for purposeful computations. An inspiring first example for this approach is given in [2]. It became the basis of our new approach towards real-time computing in neural systems in [17]. The underlying computational theory is presented in [15], and discussed from a biological point of view in [19]. Particular computational consequences of the high dimensionality of neural microcircuits are discussed in [9]. It turns out that this approach yields superior performance in terms of noise robustness, computing speed, and size compared with special-purpose neural circuits that have been constructed by hand for a specific computational task [18]. Publicly available software for generating and simulating generic neural microcircuit models, and for evaluating their computational power, is discussed in [21].

Herbert Jaeger discovered independently quite similar phenomena of temporal integration in recurrent circuits in the context of artificial neural network models [11].

Current work addresses the application of the resulting new principles for neural computation to online processing of real-world time-varying inputs, such

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as movement prediction for visual inputs [12], speech recognition in real-time, and real-time processing of sensory inputs on a robot. Another line of current research explores the computational role of specific details of biological neural microcircuits, and the role of learning principles in this context.

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