BMC Neuroscience

Poster presentation

Computation by neural and cortical systems

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from Seventeenth Annual Computational Neuroscience Meeting: CNS*2008
Portland, OR, USA. 19–24 July 2008

Published: 11 July 2008

BMC Neuroscience 2008, **9**(Suppl 1):P66 doi:10.1186/1471-2202-9-S1-P66

This abstract is available from: http://www.biomedcentral.com/1471-2202/9/S1/P66

Introduction

A theory of computation is summarized which is being used to posit and solve the problems solved by pyramidal neurons and cortical systems. The theory is based on the premise that both information and control must be physically defined and computationally manipulated within the subjective frame of a system. These representations and computations must abide by specific objective logical rules including Boolean algebra. Moreover the theory requires the existence of a dual algebra of questions wherein there are two possible kinds; those that provide information and those that allow control. Information can be thought of as the ability of a system to answer questions subjectively posed to its environment. Control is the ability of the system to generate answers to questions it subjectively poses regarding what decision to make to effect the environment. In this view, pyramidal neurons adapt and behave intelligently by computationally determining the best questions to both ask and answer which they accomplish through the information-theoretic construct of dual-matching. They then uses Bayes' theorem in logarithmic form in their decisions to generate action potentials or not [1].

The new aspect of computational theory summarized [1-4] and exploited in this paper is that information theory, thermodynamics, and a theory of intelligence have common grounding in a logical theory of questions. The practical consequence is that one can borrow constructs, findings, and engineering methodologies resident in each to apply in the other domains. Two important examples of this include the concept of dual-matching in information theory and that of the Carnot cycle in thermodynamics.

This paper shows how the dynamical processing of pyramidal neurons corresponds to that of a Carnot cycle. This cycle operates in refrigeration mode which all intelligent systems must by reducing entropy through information acquisition and restoring it after its use in decisioning. The neural Carnot cycle forms a rectangle in temperature-entropy (T-S) space as depicted in Figure 1 and describes the dynamics of neural computation.

In phase 1 of the cycle, the neuron accepts external action potentials through its synaptic contacts. This is analogous to heat leaving the neuron from the 2^n possible external states comprising its environment. Dendrites convey these measurements to the soma where they are integrated and stored in phase 2. This process reduces the temperature of the system and the new neural partition function possessing half the original phase space volume due to storage. As shown previously [1,2], the operational temperature is β^*

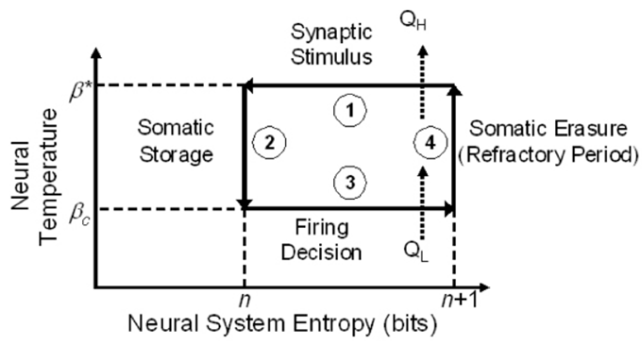

Figure 1
Carnot cycle for a pyramidal neuron having n inputs.

≅ 1 which is optimal for efficient learning [1-4]. The neuron then makes the decision to fire or not in phase 3 of the cycle thereby expending the acquired somatic information, restoring the system entropy to $n + 1$ bits. Finally, energy expended through ADP energizes ion pumps to isentropically restore neural temperature and phase space to its initial volume.

References

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