Why the Brain Can and the Computer Can't

Biology versus Silicon

Abstract

This presentation aims to follow on von Neumann's prescient *"The Computer and the Brain"* (Yale Univ. Press, 1958), and—relying on the latest discoveries—to explain how the Brain achieves ultra-low power and outstandingly high reliability (nano-)computing, while our silicon-based computers cannot. The tale will be reversed as starting from the Brain, and in particular from very fresh experimental results, for information processing and communication.

We shall proceed from the gated ion channels which are the nano-switches of the Brain. Understanding the ways ion channels communicate will allow analyzing the statistical behaviors of arrays of gated ion channels. These will be followed by unexpected results showing that highly reliable communication using arrays of absolutely random devices is possible at amazingly small redundancy factors (< 10). For computations, we will make the case for interweaving arrays of ion channels acting as distributed amplifiers, and for adapting the classical Kirchhoff current law to active (*i.e.*, 'amplified') electrodiffusion. Afterwards, we shall touch upon the ultra-low power/energy consumption where we will stress the crucial role played by hydrated ions, the very fast ion channels, and the much slower ion pumps, as well as how these behave in extremely crammed spaces. Finally, moving only briefly to the next higher level, the computational power of columnar structures will be explored in the context of large fan-in cyclic circuits.

The information conveyed will expose the reasons why our current silicon-based approaches are falling short of doing what the Brain is able to do, and also reveal a stringent need for new and more accurate computational models. As quite a few issues are still being investigated, we will conclude with a call-to-arms for both the computing and the VLSI/nano communities.