Future Information Processing: From Nanodevices to Nanosystems

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When the printing press was invented, society was provided with vastly more access to the written word. A similar 'Gutenberg Moment' is occurring as society is overwhelmed by access to massive reams of digital data from the Internet of Things. This may transform almost every aspect of our world, with new levels of qualities, quantities and uses of data[1]. Radically new Information and Communication Technologies (ICT) will be needed to analyze, store and make decisions based on the massive data streams. In many cases,the value of data will be critically dependent on the delivery time, with some data losing its value in milliseconds. Thus, technologies for real-time data streaming and data analytics are needed, and, moreover, the future generations of computers must have the ability to create insight from data. This requires a paradigm shift, i.e. from bit generation to insight generation, from raw data to actionable intelligence and suggests that architectures that promote brain-like computing may be needed.

We will examine the physics of extreme scaling of information processing devices and systems and discuss the architectural implications including system scaling. The connection of device physics in the Boltzmann-Heisenberg limits and the parameters of the digital circuits implemented from these devices will be explored. An abstraction of a Minimal Turing Machine built from the limiting devices will be used to provide insight into the "intelligence" that can be expected from a volume of matter.

In 1959, Richard Feynman[2] gave a visionary presentation in which he suggested the possibility of building computers whose dimensions were 'submicroscopic'. These submicroscopic computers remain outside of our grasp. However, nature appears to have successfully addressed the submicroscopic design challenge, and may suggest new solutions for future information processing. As will be argued in this presentation, the living cell can be conceptualized as a general-purpose computer with molecular-scale components exceeding any known inorganic computer in information throughput and which operates at incredibly low rates of energy consumption in the range of femtowatts to nanowatts. Advances in the science of synthetic biology are beginning to suggest possible pathways for future information processing technologies based on the lessons from biological systems. The essential parameters of the logic and memory hardware of biological processors and implications for the minimum-energy computing systems will be discussed.

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[1] T. Fisher, "Our Gutenberg Moment", The Huffington Post, July 23, 2013 http://www.huffingtonpost.com/thomas-fisher/our-gutenberg-moment_b_3636312.html

[2] R. P. Feynman, in: *Miniaturization*, D.H. Gilbert, Ed. (Reinhold, New York, 1961), pp. 282-296