Information Processing in the Presences of Variability and Defects of Nanoscale

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Short range and long range order in chemical self-assembly, varying chirality nanotubes, increased threshold voltage variations in silicon nanoscale transistors, variable resistances and capacitances of interconnect wiring on a semiconductor chip, and increasing defect rates with scale, are common features of nanoscale "systems". A working approach of making "complex systems" overcome these limitations is to introduce programmability. One example of this are the field-programmable gate arrays that combine transistor-based logic resources to assemble an information processing system. However, these gate arrays succeed by a large increase in power and poor utilization of the resources, i.e. by being very inefficient.

Nanoscale, where resource capacity expands by another factor of thousand, makes this problem extremely difficult and the information processing capability of the nanoscale components largely squandered through conventional hardware-based approaches of configuring.

In this presentation, I would like to visit this problem from the perspective that information processing in a complex system, instead of looking for an exactly and quantitatively precise right or wrong answer from a precise set of inputs, should perhaps be working towards finding an inexact answer or answers based on imprecise inputs, imprecise models of behavior, by using the imprecise resources. That is, variability and defects are built-in in the information input, information output, and the information processing elements - at all scale of time, dimension, energy, etc.

How could one make such a system work?

If one can, it allows one to achieve robustness at low power with imprecise resources and it would be useful for a large number of interesting problems of control and decision making that are inherently complex and multi-scale: economics, human interactions, traffic and vehicular control, medical decisions, finance, to name a few.

I will use examples drawn from probabilistic behavior of devices and their use in circuits, adaptation behavior at different scales, creation of robust networks for information transmission, and computing drawn from responding to exceptions rather than known and understood behavior, to point to a potential direction which may be fruitful for nanoscale "systems" achieving information processing capabilities that are significantly beyond those of current models.