Chapter 76
An Advanced Architecture of a Massive Parallel Processing Nano Brain Operating 100 Billion Molecular Neurons Simultaneously

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ABSTRACT

Molecular machines (MM, Badjic, 2004; Collier, 2000; Jian & Tour, 2003; Koumura & Ferringa, 1999; Ding & Seeman, 2006) may resolve three distinct bottlenecks of scientific advancement (Bandyopadhyay, Fujita, Pati, 2008). Nanofactories (Phoenix, 2003) composed of MM may produce atomically perfect products spending negligible amount of energy (Hess, 2004) thus alleviating the energy crisis. Computers made by MM operating thousands of bits at a time may match biological processors mimicking creativity and intelligence (Hall, 2007), thus far considered as the prerogative of nature. State-of-the-art brain surgeries are not yet fatal-less, MMs guided by a nano-brain may execute perfect bloodless surgery (Freitas, 2005). Even though all three bottlenecks converge to a single necessity of nano-brain, futurists and molecular engineers have remained silent on this issue. Our recent invention of 16 bit parallel processor is a first step in this direction (Bandyopadhyay, 2008). However, the device operates inside ultra-high vacuum chamber. For practical application, one needs to design a 3 D standalone architecture. Here, we identify the minimum nano-brain functions for practical applications and try to increase the size from 2 nm to 20 μm. To realize this, three major changes are made. First, central control unit (CCU) and external execution units (EU) are modified so that they process information independently,

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second, CCU instructs EU the basic rules of information processing; third, once rules are set CCU does not hinder EU-computation. The basic design of the proposed nano-brain is a dendrimer (Hawker, 2005; Galliot, 1997; Devadoss, 2001; Quintana, 2002; Peer, 2007), with a control unit at its core and a molecular cellular neural network (m-CNN, Rosca, 1993; Chua, 2005) or Cellular Automata (CA, Wolfram, 1983) on its outer surface (EU). Each CNN/CA cell mimics the functionality of neurons by processing multiple bits reversibly (Rozenberg, 2004; Li, 2004; Bandyopadhyay, 2004). We have designed a megamer (Tomalia, 2005) consisting of dendrimer (~10 nm) as its unit CNN cell for building the giant 100 billion neuron based nano brain architecture. An important spontaneous control from 10 nm to 20 μm is achieved by an unique potential distribution following $r=a \sin k\theta$, where r is the co-ordinate of doped neuron cluster, k is the branch number, θ is the angle of deviation and a is a constant typical of the megamer architecture.

INTRODUCTION: ESSENTIAL FUNCTIONS OF NANO-BRAIN

The core architecture of a nano-brain whether operating in a nano-factory, functioning as a nano-surgeon or nano-computer could be the same. The architecture may consist of a control unit connected to all execution parts following *one-to-many* communication principle. In our recently described proto-nano-brain (Bandyopadhyay, 2008), we have demonstrated this principle in practice. The principle states that, if a large number of molecules are connected radially to a single molecule then by tweaking the central molecule one can logically control all radially connected units at a time. To control the logic operation of a large assembly, we need to control only the central molecule, which we name the central control unit (CCU). Currently, the CCU can send only one instruction without any external interference. The reason is that a CCU, which is a molecular switch could be excited to a particular state, and only other possible transition of this molecule would be returning back to the normal state. Therefore, remotely, without any human interference CCU can send only one instruction. We wish to develop it in such a way that it is able to send a series of logical instructions to the execution units (EU) during its operation. Only then, the complete architecture would execute series of operations one after another by itself, independent of any external stimuli or human interference (Koumura, 1999). This is important as it is not practical to instruct the control unit of a nano-factory several times for completing the task, or instruct the control unit of a nano-computer at every stages of its derivation of a math problem, or advise the control unit of a nano-surgeon its next move during a brain operation.

The fundamental element that constitutes a molecular nano-brain is a molecular neuron. A neuron is an analogue switch. Beyond a threshold voltage, continuous increase of applied bias should generate more than two conducting states in a neuron-like molecule. Unfortunately, almost all reported practical single molecule switches are binary (Chen, 1999). We reported the first 2-bit single molecule switch operating reversibly between four conducting states (Bandyopadhyay, Miki, 2006). Since then we have tested several multi-electron processing organic systems and invented as high as 4-bit molecular switch operating reversibly between 16 distinct conducting states (Simic Glavasky, 1989). Compared to an analogue switch, 16 choices may appear low, however, because of its simultaneous response in coherence with all neighbors, it can process massive information compared to the existing processors. Recently we have demonstrated such a massively parallel computation on an organic molecular layer (Bandyopadhyay, Pati, 2010). Since molecules are redox active, it has been possible to generate a