Towards more effective computing: using the nano computing platforms

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With the continual down-scaling of transistors, basic building blocks of computing platforms, we will soon be working with nanometer scale devices. Historically looking, the civilization follows the analytical “top-down” concept of material handling since the invention of the first primitive tools. In the nanoscale domain the analytical approach foresees the manipulation of molecules, atoms or even sub-atomic particles. Currently the approach does not offer any exact solutions, neither in theory nor in practice. Consequently, great stress is being laid upon the feasibility of the complementary “bottom-up” synthesis approach. The latter builds on the existence of elementary particles, basic building blocks of more complex entities (i.e. processing structures, materials, etc). One of the proposed gnostic processing platforms is the Quantum-dot Cellular Automaton (QCA) composed of cells, each comprising four quantum dots, placed in the corners of a square, and two electrons. The device was introduced in the early 1990s by C. S. Lent. Due to electrostatic repulsion, the cell confined electrons tend to align along the diagonals. Each diagonal configuration can thus be used to represent one binary logic value. The described feature makes the migration from the current CMOS platform to the new one quite straightforward.

Our group has been involved with research of alternative computing methods (e.g. fuzzy logic) for quite a long time. Throughout our research we often have to concentrate on performance and reliability aspects, thus the problematic of compact data representation is a frequent member of our agenda. For example, from the space complexity point of view the ternary system offers a more economical representation of numbers than the binary system. An even more serious issue in computing systems is the representation of real numbers, which, even though they are nowadays represented with 32 or more bits (basic entities), are still only a shadow of the mathematical definition of Real numbers. In this view we tried to extend the QCA platform.

The initial research was principally focused to the theoretical evaluation of a hypothetical cell, consisting of a continuous circular tube with two confined electrons. This would in theory allow the electrons to move freely inside the tube, at same time always retaining maximal spatial separation due to Coulombic repulsion. This gives the electrons a possible infinite range of unique arrangements, i.e. a continuous interval of angles - [0, 360) degrees, each achieving maximal inter-electron separation. The described feature promises the representation of any arbitrary real value using only one basic building block, i.e. one cell. Unfortunately, preliminary calculations show that achieving cell neutrality, required for successful data propagation, is an extremely difficult if at all manageable task. This has redirected our focus to multi-valued QCA cells. We developed a ternary QCA cell, comprised of eight quantum dots and two electrons, which is capable to represent three logic values. The promising behavior of the basic logic primitives led to the design of devices capable of ternary data propagation, ternary processing and ternary memorizing. Our current research is focused on material research; search for materials that would allow the implementation of the proposed computing paradigm.