2007 Society for Design and Process Science
Printed in the United States of America

EDITORIAL
BIOLOGICALLY INSPIRED COMPUTING

Those following the evolution of the Society for Design and Process Science (SDPS) are well aware of its struggle to discover and consolidate the foundations of transdisciplinary paradigms. The society was formed on the understanding that it will serve to pioneer in bridging the gap between Cartesian mechanistic era and the new era which is dominated by sciences of complexity and transdisciplinary education. It is in this endeavor that biologically inspired computing became a candidate in forming the girders of the bridge.

During the 20th Century we have seen tremendous changes, socially and scientifically. We have seen revolutions which impacted the destiny of human race almost on every possible front, resulted in political upheavals which have shaken the human society from its foundations. Scientific findings that simply uprooted centuries old dogmas which resulted in engineering achievements which was, not long ago, almost beyond science fiction. And no doubt tomorrow's revolutions are likely to be even more spectacular. The speed of change has been dizzying, it is almost beyond belief that not long ago scientists had to fight and even risk their lives to prove that earth was not flat and the sun was not rotating around it.

But absolutism and determinism embedded in almost all belief systems engraved and embedded in psyche of human society influenced the modern sciences that developed during the last four hundred years. It became the desire of early scientist to understand the "clockwork" of our universe. The Cartesian mechanistic era, as it is sometimes referred as, triumphed, modern sciences were created and scientific philosophy and scientific inquiry replaced absolutist dogma. Never the less determinism (renamed as "mechanistic thinking") remained at the core of our modern sciences which continues to this present day. During this era two important theories went against the current, the theory of evolution and the uncertainty principle. The theory of evolution has in its roots (even tough it may not be recognized during its early days) in uncertainty and mutation. It became clear that the evolution of species cannot be explained without the mechanism of mutation. However it was in the principle of uncertainty that, the recognition of the fundamental nature of probability and uncertainty in the nature is explicitly stated.

During the 20th Century we witnessed unprecedented growth and explosion of technology and information. And this resulted in a greater growth in complexities in interconnections and interrelationships associated to information processing and communication. Then gradually, but surely became obvious that the Cartesian mechanistic sciences were unable in providing effective means of dealing, analyzing and synthesizing these interactions. The new problems were almost always combinatorial and exhibited certain characteristics foreign to Cartesian or Newtonian formalisms. The concept of neighborhood which is the basis of all differential formulations of Newtonian physics has lost its meaning in this new world of combinatorics. It was during this period that we witnessed the birth of a collection of tools which would attempt to deal with problems which appeared to be insurmountable. Many of these tools loosely described to be related to problem solution capability that exists in natural processes. The problem solving, implies the existence of a regulatory system and almost always point to a living organism. That is how bio inspired computing has started.

Bioinspired computing is a field of study which loosely links topics of connectionism (such as depicted by neural networks), social intelligence (depicted as group behavior) and system theory or the theory of complex system (depicted in emergent behavior).

Taking these, one by one, connectionism is generally associated with the modeling of human brain by modeling individual neuron behavior and interconnecting these simple processing units into complex networks. The widely known connectionist models are referred to as neural networks. Even though claims that these are models of the human brain is diminishing, never the less, certain levels of biological relevance remains. But what is more important is the fact that these models created a rich research field and revealed some mechanisms relevant to decision making and learning processes. And even more importantly, neural networks has removed the burden of developing mathematical models, formulations and algorithms in solving complex, highly non-linear and type of problems, often which the physics behind is little understood.

The second area of bioinspired computing is the social intelligence or the collective behavior. Although closely related to the complex systems this is taken to be a separate research area as in this case the group behavior is a result of collective intelligence sometimes governed by competition and collaboration among individuals or consensus decision making process of various kinds. The complex systems on the other hand are characterized by "emergent" behavior which results from elemental interactions with no obvious association to the emerging response. Somewhat the distinction is blurred and sometimes artificial. The most commonly known algorithm of collective behavior is the particle swarming algorithm (PSO).

The last area which the bioinspired computing is associated with is the complexity and/or the system theory. The main element which describes complexity is the "emergent" behavior. This implies that certain micro-behavior at the elemental level result in an ordered or patterned behavior at the system level. This can be observed in plants, bacteria and living organisms.

What ties these areas together is the stochastic behavior and uncertainty and the balance between the chaos and the order. Never the less the discovery and understanding the fundamentals behind the behavior of biological system remain the main challenge, without of which we can only mimic the reflections of the reality. Having stated that, even with these crude imitations we are producing results that outperform some of our well established classical methods. But with the success, the scientists' desire to extract fundamentals is somewhat taken aback or at least partially replaced by the notion of imitation. And question of what drives all these processes and weather the presence of uncertainty is more fundamental to biological processes is remain to be discovered. It seems that the uncertainty in biological systems is more fundamental than commonly appreciated. The uncertainty may even be deeper rooted in behavior of matter itself originating from behavior of the quantum.

Any biologically inspired system to be successful needs to be able to do various processes as closely as possible to its biological counter parts. In modeling this analytically or numerically one faces a number of major problems, the most important of which is the understanding of biochemistry which drives the biological systems. Here one faces the most serious hurdle, down to what detail we need to understand and model biological interactions, is it going to be at the molecular level or even finer levels? And how effective to be able to do this when such a magnification can only make computing of the related process impossible. That is why all biologically inspired computing finds a compromise in the expense of the inspiration. There is no evidence, yet, that more complex neuron models outperform the simpler versions. Having accepted that the compromise is a fact of life and we will not be able to develop exact copies of the real systems, then the biologically inspired computing faces two challenges, (a) how do we represent the population, or in numerical sense, variables of a given system? And (b) what evolves them, in other word how does the collection of members representing a population change their state.

Firstly the variables chosen for the problem at hand should be meaningful with respect to the biological system or the evolution process associated with the biological system. To give a simple example, binary representations are used in describing topology of networks by means of the connectivity matrices and binary representations are also used to genetic algorithms. It is tempting to use them in network design. It turns out that in most networks the topology described by a binary connectivity is sparse in density and not effective in processing, leading to slow processing or even unrealizable networks. Therefore representation is crucial to successful execution of biologically inspired processes. The issue of sparsity in representing the topology of a network, if studied in depth, reveals associations between high levels of redundancy leading to excessive expansion of design space. The question of representation discussed above relates to a numbering scheme as well as representing the computing structure (for example of a neural network) which is different to the classical question of data representation which involves issues such as freedom, constraint, redundancy, noise and information content, compression transformations and mapping which can be seen as a question of information refinement. And the questions of representation in both sense applies to all the processes which involves population driven computing. In other word in a biologically inspired computing the structure of the computer, the structure of a neural network or scheme of and the representation of data are tightly interlocked. In the absence of identifiable physical model and lack of procedural description of the problem analysis, the data representation, data refinement (pre-processing) and data evolution becomes crucially important. Fortunately, as far as classical data processing concerned, an array of classical tools are in our disposal, such as FFT, wavelet, principal component analysis and many more to refine and even map data into different domains for better performance. The same cannot be said for the actual numbering schemes or the topological association that one needs to represent the variables or the "computer." It took many years for researchers of Neural computing to realize the association between network structure and data distribution as depicted in years of debate of linear separability, the shift invariance and many similar issues. However we are no closer to discovering a systematic way of deciding what is the right biological computing for a given problem.

And the second important issue is the process or the evolution of population or species to the next generation. The neural networks assumes a certain trigger mechanism for information transfer, genetic algorithms assumes various genetic evolution mechanisms and rules driving cellular automata or L-systems or swarm motion. Many of these methods appear to follow different schemes of evolution but what is common to many certain characteristics of the mechanism (or rules) with which evolution is performed. They all have the search directionality degree of which is determined stochastically. This in terms of genetic algorithm relates to the genetic information transfer and biased-random selection of individuals to enter into the crossover operation. The randomness in all these evolution processes varies from levels of random walk and the simulated annealing. Level always depends on various search strategies selected by the end user.

There is no doubt that we are dealing with concepts that are new and revolutionary in comparison to the conventional and classical sciences. To classical sciences with their rigid laws and foundations "inspiration" as a scientific tool seems to be too farfetched and even alien. But the success of these new tools are in no doubt and their persistence to grow and improve is the confirmation of their effectiveness, especially in dealing with complex problems.

It is with these backgrounds that the current edition of SDPS journal was proposed. The selection of authors represent only a small section of the research which goes on in this field. As one of the fastest growing area of research it would have been impossible to be exhaustive in our selection. I hope that SDPS in their endeavor to be the pioneers in developing new sciences to take us beyond Cartesian mechanistic era embraces bioinspired computing as the beacon in their search.

September, 2007 Ibrahim I. Esat