Modeling of Life and Cognition: Synthetic, but Not Alchemic

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In response to Question 11: "What are the characteristics and roles of synthetic models?
SMLC 2013: Section c) Possibilities, limits, ways and impacts of the synthetic modeling of life and cognition.

Abstract. Synthetic modeling of life and cognition can be considered a methodology of the future only if it escapes the limitations of traditional laboratory approach which was shaped by the alchemic tradition. The word "synthetic" associated with synthetic polymers together with the word "artificial" (as in "artificial intelligence") are symbols of already fading away paradigm of research in which reality is simply deconstructed into ingredients, from which by the reversed order of steps it is possible to reconstruct objects of our study. All modeling is by the definition artificial, whether models are material, abstract, mathematical, or digital. What was missing in the past was the recognition of the hierarchical forms of complexity in life and in mechanisms of cognition. And it is complexity and the new methods of overcoming its limiting consequences which should be in the focus of new methodology. We can learn a lot in this respect from the natural mechanisms of information integration.

Extended Abstract. There is a big danger of confusion in the use of expression "synthetic modeling" for a new methodology in the study of life and cognition. After all, all modeling is by the definition artificial, whether models are material, abstract, mathematical, or digital as in simulations. The danger in the use of the word "synthetic" is through its association with the very conservative view of the physical world and the reductionist or mechanistic methods of its study in which the subject is deconstructed into its components, and it is consider possible to reverse the order of steps and reconstruct the original.

The word "synthetic" in the context of modeling life brings back several episodes from the study of the subject. In the earliest, Islamic alchemist Geber (Jābir ibn Hayyān) in the 8th Century set as his goal *takwin*, synthesis of artificial life including human life. He even claimed in his *Book of Stones* the possession of knowledge how to create simple forms of life (Haq, 1993).

One thousand years later, Friedrich Wöhler finally achieved, rather accidentally the synthesis of the first organic compound - urea from (arguably) completely inorganic substrates. This episode was used in the 20th Century by Peter J. Ramberg to create commonly perpetuated myth of the defeat of vitalism at that time. Synthesis of urea actually contributed to the demise of vitalism, which came much later with the development of genetics and understanding of metabolism, but the 19th Century was already the beginning of the great time of synthetics. Synthesis of polymers, from Bakelite in 1907, through nylon in 1935 (although the "nylons" as an attribute of femininity entered the stage in 1940), to the wide range of organic compounds which nature did not bother to create itself became a symbol of modern times.

The career of another medium for synthetic models related to computing and computers is much shorter, but equally or more spectacular. Here too, the goal was from very beginning very ambitious to create artificial intelligence. Alan M. Turing (1950) expected existence of such artifacts by the year 2000. Yet, we do not have genuine artificial life, nor artificial intelligence, and we still do not know what they actually are in their natural or artificial form.

So, isn't it an anachronism to search for the new methodology for the study of life and cognition in their synthetic or artificial models? Yes, it definitely is, if we try to stay within the old paradigms of synthesis and artifact. What exactly were these paradigms? Why did they fail?

Although the details were changing in time, the foundation of the traditional view of synthesis and artificial creation is in philosopher's stone. All objects of our experience are composed of the substance which can be transmuted from one form to another with the help of philosopher's stone, base metals into precious ones, dead matter into living creatures. More recently, magic procedures to alter qualities were replaced by clearly defined human action which is changing components of molecules to produce desired material properties. What remains common is the substantial character of the substrates and products of action.

Study of life and organic compounds brought the picture of increasing level of complexity, but complexity in the quantitative sense. Molecules of DNA may consist of millions or billions of nucleotides, but its complexity in relation to simpler organic compounds is a matter of numbers, since it is built from hydrogen, oxygen, nitrogen, carbon and phosphorus as majority of other organic substances.

Similarly, in the picture of cognition seems to be involved the same type of complexity. Human brain has billions of neurons connected by the network of dendrites and axons. But the work of neurons is simple and consists in transmission of electric signals collected through multiple dendrites and sent through the single axon. Both systems seem to produce so complex behavior simply through summation of the work of the huge number of components.

Simplicity of the components brought a great revolution in thinking about life and cognition that what matters are not substantial properties of the systems, but their organization, and therefore information. Similar revolution happened in the analysis of language, more specifically in computation. Turing showed that the process of calculation and consequently of any formalized procedure performed within rules of traditional procedures of logic can be decomposed into a few basic operations which can be performed by a very simple machine. W. S. McCulloch and W. H. Pitts (1943) demonstrated six years later that the same type of work can be done by the network of neurons.

At this point we can see very clear reason why the synthetic modeling should involve the three basic forms of models based on software, hardware and wetware. But are we far enough from alchemic paradigm by the recognition of the fundamental role of information instead of substance? Are we really closer to understanding of life and cognition now, than fifty years ago? (Simeonov *at al*., 2012; Schroeder, 2012)

Why is so promising direction in modeling of cognition as artificial neural networks dead? We can explain the mechanism of re-creation of the chemical composition of the proteins, but how are the geometric – structural characteristics of their molecules encoded and implemented? Why do we have only left enantiomers of naturally synthesized amino acids, but equal number of left and right artificially synthesized?

The list of questions, especially regarding encoding of operational genetic information is becoming not shorter, but longer in time. It is difficult to believe in any breakthrough, without some diagnostics of the shortcomings in the conceptual framework, simply through continuation of already used methodology of modeling some selected fragments of natural mechanisms in a laboratory setting (of any time, including computer simulations).

In the opinion of the author, the main problem is in the failure of the proper recognition of the forms of complexity. Here we have continuation of alchemic thinking in which integration was not much more than putting ingredients into a pot, possibly stirring the content while reciting some magical incantation. Life and cognition are phenomena within hierarchically structured systems which require a new more holistic methodology (Schroeder, 2012). This type of methodology can be developed through the analysis of information integration taking place in natural systems, in particular in human brain (Tononi and Edelman, 1998a, 1998b; Schroeder, 2009).

The objection to oversimplification of the concept of complexity applies equally well to wetware modeling, as to hardware and software modeling. The problem of complexity in the context of computation is a result of a vicious circle. Turing, who definitely was a genius, showed that process of calculation as well as of formal logical reasoning as long as they have recursive form can be decomposed into simple steps which can be carried out by machines, and what is more important it is possible to construct a universal machine which can carry out work of any specialized machine (Turing, 1936). Since the use of formal languages has recursive form, this means machines can perform functions of the brain which consist in the use of language. Language is the most familiar information system. Therefore, machines can perform all information processing done by the brain. Of course, the conclusion is totally incorrect.

This wrong conclusion has more detrimental consequences, than only false conviction about implementation of artificial intelligence. It diverts attention from looking for the new methods of dealing with complexity perpetuating unjustified view that complexity of life and intelligence can be reduced simply to algorithmic complexity (Schroeder, 2013c).

Thus, synthetic modeling methods are the future of the study of life and cognition, however under the condition that this methodology incorporates study of complex systems, in which the concept of information integration in the context of the dynamics of information seems most promising (Schroeder, 2009, 2013a, 2013b).

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