TRIZ Evolutionary Trends in Biology and Technology: Two Opposites

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Abstract

We examine the concept of evolution in technology and biology. It appears that most of the trends in these two domains have different meanings and development. Engineering is older than mankind, because numerous animals make tools and change the environment for their needs and requirements. The conflict of strategies in technology and biology can cause serious problems. There is a challenge for the dialectical synthesis of these two opposites. In practice it means that the technology should address its roots and see how biological functions are carried out. This can teach us a lot, because biological solutions are often more reliable, energy efficient and cleaner than conventional technology.

Keywords:

TRIZ, evolution, biomimetics

1 INTRODUCTION

The trends of technology evolution developed in TRIZ are very helpful in product design and strategic management for choosing the cheapest options. As these trends reflect the popularity of certain inventive principles amongst engineers there is the question whether these pathways are objective. Our thinking processes reflect how we, as living creatures, make decisions. This means that patterns we use to solve problems should be also found in animate nature. Decision making is a necessary feature for the definition of life. We can regard morphology as the result of communal cellular decision making (genes define the limits of abilities to act, but still there is a lot of opportunity for making individual choices). We need to know whether we are "programmed" with 40 inventive principles of thinking (or 76 standards) by our nature, or do these principles represent technology as a totally artificial phenomenon? In other words, are these principles (evolutionary trends) inherited or invented? Are there general laws in nature which, reflected in technology, gave G. Altshuller [1] the idea of evolutionary trends? Answering this question opens the way to develop this concept more systematically. In this paper we describe our quest to find an answer.2 Are technology evolution trends objective or subjective?

2 ARE TECHNOLOGY EVOLUTION TRENDS OBJECTIVE OR SUBJECTIVE PHENOMENON?

2.1 Technology and the laws of nature.

Invention and creativity in design very much belong to individuals. Design as a social phenomenon may be regarded as objective. To prove that evolutionary trends in technology are objective we should go to the super-system and have a look at society as a natural phenomenon. Usually the reason for looking to nature for solutions is to enhance technical functions; this is the domain of a relatively new field of engineering – biomimetics or bionics. But in fact nature does not contain many of these functions, and probably doesn't have the means of deriving them. For instance, one of the basic features of living systems is the appearance of autonomy or independence of action, with a degree of unexpectedness directly related to the complexity of the living system. This gives living systems great adaptability and versatility. In general engineers do not appreciate unpredictability in technical systems; indeed they try to avoid it by any means. But we need to consider this even in our current technology, since nearly every technical system is actually a combination of a technical system in the narrow sense, and a living (usually human) system, which is the operator of this technical system. This immediately suggests a broader and more general definition of the very term – "a technical system" – a biological system, part of the functions of which is delegated to a device that is mostly artificial and/or non-living. A good example would be agriculture. This consideration is commonly omitted; technical systems are often considered in isolation, neglecting any broader context despite the fact that engineering is really a subset of human behaviour. At best this can lead to reduced effectiveness, at worst it produces technological catastrophes. So, there is good reason to learn from biology how nature deals with extreme complexity and uncertainty.

If we find TRIZ evolutionary trends in the super-system in living nature we can regard them as objective. This opens a range of possibilities for bio-inspired design. But if not, why not?

2.2 TRIZ as a bridge between nature and technology

We started to merge TRIZ with biology for the needs of biomimetics (science that takes ideas from biology to implement them in technology) in 2000-2002 [1], [2], [3], [4], [5], [6], [7]. The aim was to use TRIZ as a bridge between biology and engineering to enable us to implement natural principles in design and technology. It was also very tempting to see whether TRIZ evolutionary trends work in animate nature as this could contribute to evolutionary theory. We had a look at morphological development and found that nearly all the trends work in biology [6], [8]! Analysing biological phenomena and the laws and patterns in biology, we found practically all the "inventive principles" in biological systems at all levels of complexity – from cell to ecosystem. This is the first evidence that biological and technological evolution reflects a more general reality and therefore looks similar.

This means that the answer to the first question was positive. Inventive principles described in TRIZ are objective and reflect the rules of development of a living system. But there is always the danger of a mistake as very often two phenomena that look very similar may not always have similar causes of origin. The next step was to see whether the mechanisms that drive changes in animate nature could be found in technological development. If yes, how we can use this?

3 BIOLOGY AND TECHNOLOGY – TWO OPPOSITES AND CHALLENGE FOR SYNTHESIS

We have analyzed 500 biological phenomena, covering over 270 functions at least 3 times each at different levels of complexity – from cell to ecosystem. In total we have analyzed about 2500 conflicts and their resolutions in biology, sorted by levels of complexity [9]. As a result we revealed some crucial differences that should be discussed.

To enable us to compare parameters from the technological and biological domains we established a logical framework based on the mantra – "Things do things somewhere". This establishes six fields of operation in which all actions with any object can be executed: *Things* (substance, structure) – this includes hierarchically structured material, i.e. the progression sub-system–system–super-system; *do things* (requiring energy and information) – this also implies that energy needs to be regulated; *somewhere* (space and time). These six operational fields re-organise and condense the TRIZ classification both of the Features used to generate the Conflict statements and the Inventive Principles [10]. This generalisation is considerably more logical and easier to use than the 39 x 39 Contradictions Matrix as it encompasses more parameters that were previously missing. Moreover, our 6 x 6 matrix constructed from these fields has no blank cells. This more general TRIZ matrix is also used to place the Inventive Principles of TRIZ into a new order that more closely reflects the biological route to the resolution of conflicts. We call this new matrix the BioTRIZ matrix. We can now compare the types of solution to particular pairs of conflicts in technology and biology. Although the problems commonly are very similar, the inventive principles that nature and technologies use to solve problems are very different. In fact the similarity between the TRIZ and BioTRIZ matrices is only 0.12, where identity is represented by 1 (Figure 1). This is actually not surprising, because the technology appeared as a response to the weaknesses of biological systems. But this difference tends to increase and finally has led to numerous problems such as our current ecological crisis. This is the right time to look at biological systems and the ways, techniques and strategies they employ for problem solving.

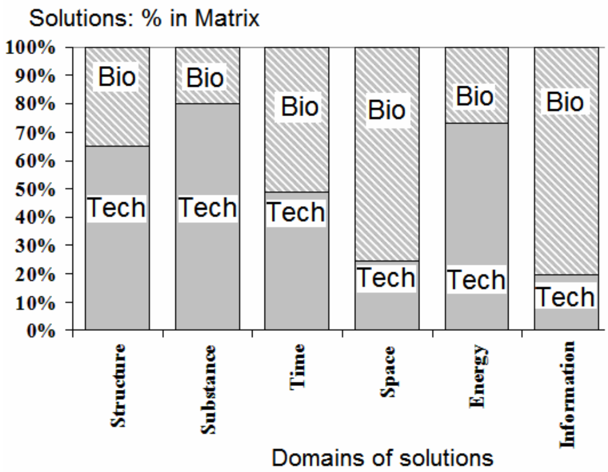

Figure 1. Biology and engineering: a comparison of matrices.

As it is clear now that bio- and technological "design" have absolutely opposite strategies, we may even regard them as two anti-systems. Technology tends to solve problems spending energy and building up structures, changing substances – in energy and matter domains. In animate nature, problems are mostly avoided in space and resolved using information – this is a much cleverer and less energy-demanding way of problem resolution (Figure. 1). To develop the approach to such synthesis we need to know the reasons for such a difference.

4 TWO "EVOLUTIONS"

The word "evolution" is used in science and engineering in many senses. Even in the domain of evolutionary biology there are at least 24 different concepts or types of mechanism of evolution that work in different contexts [6]. We also need to take into the account that there are different hypotheses of social evolution. And now thanks to G.S. Altshuller [1] we have yet another "evolution" – technology. So, what is the difference between the evolution of life and changes in technology?

Developing Bio-TRIZ over the last 6 years for the needs of biomimetics we noticed that evolutionary strategies in life and technology do not match each other. This happens in two areas of technology and biology: morphology (we call this "hardware") and information or regulation mechanisms (we call this "software"). The natural evolution of biological systems clearly shows the increasing importance of the informational (psychical, communicational, behavioural) part of life [9]. Those systems which failed to have the advanced "software" are eventually defeated. Gigantic animals armoured with huge offensive and defensive weapons lost in competition with animals with less armoured, but much more advanced behaviour. A more intellectual system gives not only a quicker response, but develops long-term adaptation of *itself to the environment* and/or adaptation of the *environment to itself*. Evolution of morphology without comprehensive "software" support invites extinction.

On the other hand here are also some processes in human societies that cause change and affect evolution, which are apparently not rational such as cultural patterns, e.g. fashion, social traditions, etc. In biological systems we can observe the same situation – for instance, very bizarre acoustic or visual signals in the system communication courtship displays seem to have no survival advantage at all.

LIVING BIOLOGICAL NATURAL SYSTEMS	**NON-LIVING TECHNICAL ARTIFICIAL SYSTEMS**
1. Operate within relatively narrow conditions of temperature, pressure, chemical environment, etc. Utilisation of high-energy electromagnetic fields, radiation and low temperatures is absent.	1. Operate within wide conditions, which are beyond the tolerance of living creatures. Utilisation of high-energy electromagnetic fields, laser, radiation, extreme temperatures, and pressure is wide-spread.
2. Complex living systems tend to keep balance – static (homeostasis) or dynamic (homeorhesis) due to closed cycles of energy and substance.	2. Most of human technologies are open-ended "cycles", which cause most of problems in various types of imbalance and lack of sustainability.
3. Relatively slow rates of evolution.	3. Very fast and accelerating development.
4. Long term sustainability.	4. Short term effectiveness ("I want it now ")
5. Slow processes are wide-spread.	5. Slow processes are considered as shortcomings.
6. Complex ecological systems tend to drift from *r*- ("cheap", small, short living organisms) to K-(large, long living) mode.	6. Economical forces make steady shift from K- to *r*-mode in products.
7. Biological systems mostly avoid long-range transport.	7. Contemporary industrial systems are unimaginable without massive global transport.
8. Living creatures mainly participate in all the processes in which it is concerned as a central figure.	8. Evolution of technology goes from mechanisation via automatisation towards nearly total replacement of humans in the manufacturing process.
9. Morphological trends throughout evolution: oligomerisation of effectors and metameric parts of the body.	9. Morphological trends throughout the evolution: mono-, bi-, poly-systems (polymerisation of monomeric parts).
10. Replication, reproducing, cloning, metamerisation: multiplication of units	10. Segmentation: reduction of the unit.
11. Newly evolved biological systems do not necessarily replace the old ones, but often exist in parallel.	11. Typically new technology replaces the old one.
12. The most common type of manipulation and locomotion: oscillation, reciprocation, pulsation.	12. The most common type of locomotion and manipulation: rotation.

Table 1. Some differences between nature and technology

Since a technical system is a living system in which otherwise missing or insufficient functions are added and delegated to technical (non- devices, so technology allows us *to avoid natural selection* and become adapted more quickly. It is great to get something new (function, structure, organ, etc.) without the long process of evolution! But, being connected to its living part, the evolution of technology is directed by mind, culture, and social and economic environment. In other words, the development of technology is a development of human ideas that have their material implementation in a particular cultural, sociological and economic environment. So, another question is: what did G. Altshuller describe as "the laws of technological evolution”?

Adjusting the environment, in whole or in part, *to an organism's needs* eventually has led to the appearance of tools, constructions (nests, burrows, beavers' dams) and finally to human technologies with the most sophisticated artefacts. (Do not be confused by biological evolution *s.str.* that describes the mechanisms of *adaptation of the organism to the environment*). This artificial “nature” is the contemporary environment, at least for humans in modern society. If we consider the evolution of human technologies throughout history, we also notice that hyper-development or over-estimation of the material aspect of any artefact which was not supported by the relevant and adequate “soft-ware”, finally lost the competition and gave way to the smarter technologies loaded with information. There are numerous examples in the history of armour and weapons, energy-supply technologies, etc. [2].

Evolving towards increasing complexity, technology shows more similar patterns of development to social transformation than to the patterns of morphological evolution that we can see in life [11]. But some features of biological evolution of morphology are common to some evolutionary trends of technical development. It might mean that transformation of the environment and adaptation to it have different evolutionary strategies (table 1). We can make a longer list of differences between biology and technology, but we have pointed out only the main features. Some technologies are already sensitive to the danger of this growing gap and are making attempts to improve this opposition. For example, the founders of permaculture tried to formulate new approaches in agriculture and related spheres of economy [12].

5 CONCLUSION

In our research we have found similarity in patterns of design, but not in evolutionary trends or mechanisms of development.

Evolution in animate nature and technology are totally different phenomena. The future of technology is in its ability to deal with complexity. Knowing natural principles that we learn from biology may contribute to the future of technology as this knowledge reveals the laws of any complex system development.

There are two evolutionary strategies – adapt to the environment and adapt the environment. Each works differently but they should be balanced. If unbalanced these strategies become dangerously separated as their driving mechanisms do not match. The simple transfer of ideas is not enough. We need a new method in science that can provide a dialectic synthesis of these opposites.

It is obvious that we should combine the most advanced features from biological principles and our vast engineering experience [4]. BioTRIZ was developed to initiate this process. Taking into account the laws of development (not only evolution in a biological sense!) of living and non-living artificial systems within one engineering domain is the real challenge! We are confident that modifying TRIZ into its Bio-TRIZ version will make technology more ecologically sound and environmentally friendly and therefore sustainable.

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