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HYBRIDIZATION OF TECHNICAL CREATION METHODS IN BIONICS AND BIOMIMETICS

BY

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Abstract. A large number of technical creation methods are known in the process of ranking technical solutions in a technical field of interest. The independent use of these methods limits their capabilities to cover broad areas such as bionics or biomimetics. In the present paper, the combination of two such classical methods was proposed. The first is the morphological matrix method by which new solutions for solving technical problems can be reached, and the other is the diagram of ideas that allows the hierarchization and good classification of the generated solutions. Thus, the hybridization of the two methods of technical creation was done for the first time in this work and can be a useful tool for inspiration from nature in the orderly process of solving technical problems.

Keywords: biomimetics, bionics, technical creation methods, biomimicry.

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1. Introduction

“An invention is a technical solution or achievement in a field of knowledge that presents novelty and progress, compared to what has been known so far” (Romanian Academy, 1998). The fundamental attributes of the patentable idea of technical creation (product or process) are represented by the novelty of the idea, its feasibility (an indicator of the degree of achievement of a product/process under given conditions), and the technical progress of the application of the idea in the industrial field (Seghedin, 2008; OSIM, 2014; Slătineanu, 2019). In the course of time, logical technologies have been developed to formulate themes of creativity. These are based on the research and synthesis of information in the field of interest, which creates a basis for the creative theme. These creative techniques lead to a new solution, obviously superior to the existing ones.

1.1. The diagram of ideas

As a rule, thinking is subject to a great deal of information in the creative process, where the necessity of structuring all the known information, existing for the purpose of their mastery, appears. To stimulate concurrent concentration on a large number of ideas and to distinguish and classify them, the visual sense is used, with a greater impact on the human brain. One of the most important means of visualization, made on a single plane using geometric shapes, is the *diagram of ideas* (Belous *et al.*, 2014).

These diagrams allow, in essence, various ways of structuring information, ordering, and classifications, as intellectual work techniques, and creative techniques, when they are a way of stimulating creativity by providing the opportunity to discover ways of developing the technological area of interest. They can also be used to illustrate the current state of scientific knowledge in a field (Seghedin, 2008), as they were used in the works of Shah *et al.*, 2008; Bandara *et al.*, 2012; Hussain *et al.*, 2019; Hassan *et al.*, 2020. Fig. 1 shows the general structure of the diagram of ideas.

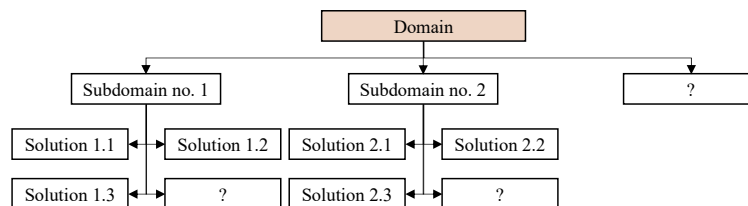


Fig. 1 – The general structure of the diagram of ideas
(Adapted from Belous *et al.*, 2014).

When drawing up a diagram of ideas, a broad area of knowledge is established. The next step is structuring subdomains, types, models, and existing

solutions or adding new levels of solutions/ideas with a high degree of originality. This results in a diagram whose complexity is directly proportional to the degree of information. The most important element of the diagram is the element "?", which symbolizes the open character of the creative method through the diagrams of ideas (Seghedin, 2008; Belous *et al.*, 2014).

The user of the diagram of ideas determines the degree of abstraction of the technique. In their elaboration, they may be missing pictures, which are replaced by symbols, text, numbers, codes, etc. (Seghedin, 2008).

1.2. The morphological matrix

It is necessary to know minimal combinatorial notions (arrangements, combinations, permutations, graphs, and finite networks) for the elaboration and finalization of the logic-combinatoric-deductive techniques and creative methods. Morphological matrices are part of the most efficient means of systematizing, classifying, generating, combining, and selecting information in science. Morphology (a term taken from biology and linguistics) is understood as a science that deals with the study of shape, structure, linking elements, and components of an entire. It presents many advantages, by being an easy way to find new alternatives, with a high degree of originality by abstracting the information present in the structure of such a morphology (even to achieve the absolute). The disadvantage of this technique is their closed and limited character, due to the absence of images. Morphological matrices may have rectangular shapes (Fig. 2) or circular shapes (Eder, 2006; Seghedin, 2008; Gassel *et al.*, 2010; Belous *et al.*, 2014).

	B ₁	B ₂	B ₃	B ₄	B ₅
A ₁	A ₁ B ₁	A ₁ B ₂	A ₁ B ₃	A ₁ B ₄	A ₁ B ₅
A ₂	A ₂ B ₁	A ₂ B ₂	A ₂ B ₃	A ₂ B ₄	A ₂ B ₅
A ₃	A ₃ B ₁	A ₃ B ₂	A ₃ B ₃	A ₃ B ₄	A ₃ B ₅
A ₄	A ₄ B ₁	A ₄ B ₂	A ₄ B ₃	A ₄ B ₄	A ₄ B ₅
A ₅	A ₅ B ₁	A ₅ B ₂	A ₅ B ₃	A ₅ B ₄	A ₅ B ₅

Fig. 2 – The general structure of a plane morphological matrix
(Adapted from Belous *et al.*, 2014).

The matrix consists of two assemblies containing five morphological elements. Thus, combining the elements of the formator assembly $A = \{A_1, A_2, A_3, A_4, A_5\}$ with the elements of the formator assembly $B = \{B_1, B_2, B_3, B_4, B_5\}$, there may be 25 possible combinations. These may be known combinations, new combinations, or divergent combinations (incompatible).

Fritz Zwicky (1898-1974) considers that the morphological matrix method does not have an imaging character until a time when all the possible combinations

of the matrix-forming assemblies (Seghedin, 2008) are encoded and visualized.

1.3. Biomimetics and bionics

D'Arcy Wentworth Thompson (1860-1948), scientist, mathematician, and Scottish naturalist introduced for the first time physics and mathematics in zoology and morphology. D'Arcy compared the structure of the four-legged skeleton with the bridges structure and he recognized *biomimetics* as science in 1917. Essentially, biomimetics or biomimetics studies processes, phenomena, structures, elements of nature, and interactions between them in order to develop artificial systems. In fact, *bionics* (published in 1960 by Jack E. Steele's contribution) refers to the observation and study of biological systems to obtain applications for the benefit of the human body. This is a combination of life science (biology), mechanics, and electronics (Belous *et al.*, 2014; Chiriță *et al.*, 2016; Vincent *et al.*, 2006; Fodor, 2019).

The work includes the methodology approached by combining two classic methods of technical creation that are applied in the fields of bionics and biomimetics for the generation of new ideas and the ranking and inventory of existing technical solutions in these fields.

2. Proposed methodology

Most of the time, technical creation methods are applied independently in the field of interest. Many of the methods can generate a large number of technical solutions that can be quite difficult and time-consuming to classify and classify.

In this paper, we proposed the combination of two methods of technical creation for obtaining new ideas (by using morphological matrices), but also the classification and ordering in the specific subfields of the topic addressed (by using idea diagrams).

Fig. 3 presents the course of the hybridization of the two methods of technical creation (diagram of ideas and the morphological matrix) in the process of innovation and inventory of known technical solutions and generation of new ideas specific to the fields of bionics and biomimetics.

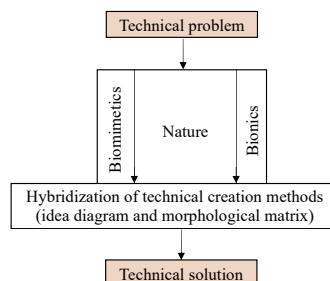


Fig. 3 – Biomimetics and bionics in technical creation.

Thus, human thinking appeals to the source of inspiration (nature), in two ways (biomimetic and bionic) to find models to follow in order to solve technical problems in a certain field.

Thus, this approach of biomimetics and bionics in technical creation can bring important contributions in nanotechnology (with particular implication in medicine), in top fields such as robotics, complex structures for materials and biomaterials, air transport, maritime, etc.

3. Results and discussions

Based on the analysis and classification of the information from the evolution of biomimetics in different technical domains, we developed the diagram of ideas presented in Fig. 4. In this type of diagram, images are missing, these being replaced by plane morphological matrices.

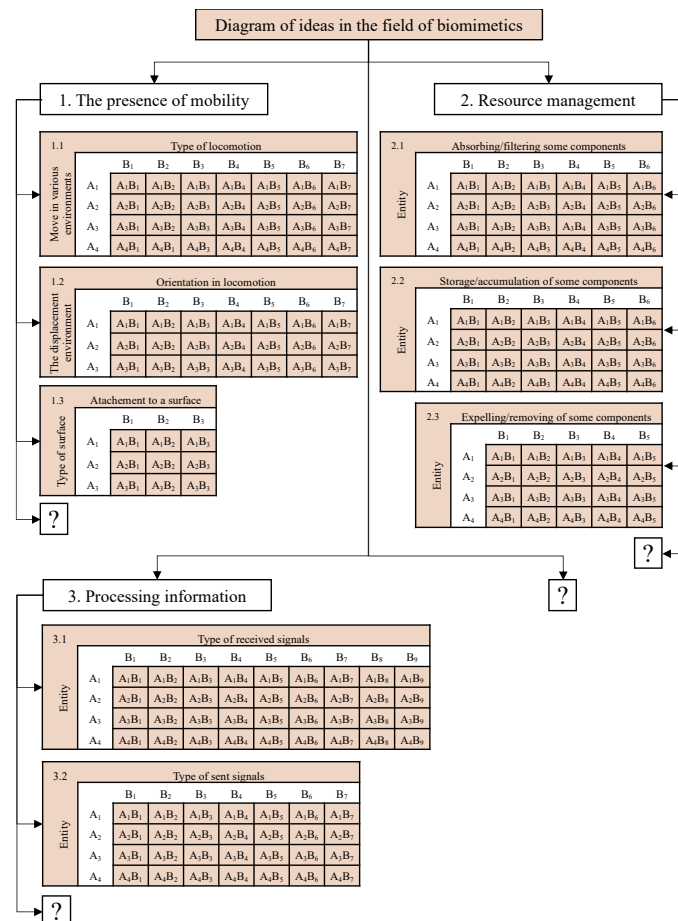


Fig. 4 – Hybridization of technical creation methods.

As a criterion for the classification of the domains, the connection between certain entities in the animal and vegetal kingdom and their way of life has been established by the functions they perform in nature, resulting in three areas: (1) presence or absence of mobility (locomotion), (2) the management of own resources and those provided by nature and (3) processing of information for various purposes. For classification in subdomains, it was established that each domain (1, 2, 3) would correspond to a certain number of morphological matrices of ideas. Plane morphological matrices were used, which are made up of two formator assemblies (A and B).

The subdomain (1) - The presence of mobility consists of three morphological matrices. For each matrix, there are set two assemblies, as in Table 1. Each formator assembly contains a number of morphological elements.

Table 1
The subdomain (1) of the diagram of ideas

1. The presence of mobility	1.1	A. Move in various environment	1	Active ground motion
			2	Active motion in water
			3	Active motion in the air
			4	Amphibious movement
		B. Type of locomotion	1	Tumble
			2	Swim
			3	Creep
			4	Walk/run
			5	Leap
			6	Flight
			7	Floatation
	1.2	A. The displacement environment	1	In solids
			2	In liquids
			3	In gases
		B. Orientation in locomotion	1	Feel touch
			2	Chemicals (odor, taste)
			3	Temperature
			4	Light (different wavelengths)
			5	Magnetic field
			6	Sound (ultrasound)
			7	Eyesight
	1.3	A. Type of surface	1	In/On solids
			2	In/On liquids
			3	In/On gases
		B. Attachment to a surface	1	Permanently
			2	Temporarily
			3	Incrementally

The subdomain (2) - *Resource management* consists of three flat morphological matrices (2.1, 2.2, 2.3), containing two assemblies with four, five or six morphological elements (Table 2).

Table 2
The subdomain (2) of the diagram of ideas

2. Resource management	2.1	A. Entity	1	Animals
			2	Plants
			3	Fungi
			4	Bacteria
		B. Absorbing/filtering some components	1	Microorganisms
			2	Particles
			3	Gases
			4	Liquids
			5	Chemical entities
			6	Energy
	2.2	A. Entity	1	Animals
			2	Plants
			3	Fungi
			4	Bacteria
		B. Storage/accumulation of some components	1	Solid
			2	Liquids
			3	Energy
			4	Gases
			5	Microorganisms
			6	Particles
	2.3	A. Entity	1	Animals
			2	Plants
			3	Fungi
			4	Bacteria
		B. Expelling/removing of some components	1	Solid
			2	Liquids
			3	Gases
			4	Electric field
			5	Chemical entities

The subdomain (3) - *Processing information* is formed by two morphological matrices, made up of two assemblies (A and B) containing from four to nine morphological elements, represented in Table 3.

Table 3
The subdomain (3) of the diagram of ideas

3. Processing information	3.1	A. Entity	1	Animals
			2	Plants
			3	Fungi
			4	Bacteria
		B. Type of receive signal	1	Tactile
			2	Pain
			3	Disease
			4	Sound/vibrations
			5	Chemicals
			6	Atmospheric conditions
			7	Light
			8	Electric/magnetic field
			9	Time and day length
	3.2	A. Entity	1	Animals
			2	Plants
			3	Fungi
			4	Bacteria
		B. Type of sent signals	1	Light (visible spectrum)
			2	Light (non-visible spectrum)
			3	Sound
			4	Tactile
			5	Chemical
			6	Mechanical
			7	Electric/magnetic field

Combining the elements of the eight morphological matrices results in 186 possible combinations ($28 \times 21 \times 9 + 24 \times 24 \times 20 + 32 \times 28 = 186$).

For example, the combination of A_1B_2 from the matrix (1.1) of the subdomain (1) assembled with the combination A_1B_4 from the matrix (3.1) of the subdomain (3) refers to an animal that moves through the water, using ultrasound to navigate. This principle is called *echolocation* and is used by dolphins. Festo[®] took this idea from nature and created the underwater robot *BionicFinWave* (Festo, 2019) which moves autonomously through a pipe system using ultrasound to avoid collision with the walls of transparent pipes. If the size of this robot would be very small (nanometric dimensions), for example through (BIO)MEMS techniques, could navigate through a patient's blood vessels to detect potential pathological elements.

The combination of A_1B_4 from the matrix (1.1) of the subdomain (1) assembled with the combination A_1B_1 from the matrix (2.2) of the subdomain (2) and with the combination of A_1B_8 from the matrix (3.1) of the subdomain (3)

inspires the idea of a terrestrial animal that can accumulate/transport solid components. It also appears that this entity must communicate with its exterior with other animals of the same species by electrical or magnetic signals.

Thus, Festo[®] created *BionicANTs*, a small robot demonstrating how autonomous decision-making and cooperative behaviour facilitate teamwork efficiently. Applications can also be found in, among others, medical, air-conditioning, and safety technology (Festo, 2019).

4. Conclusions

In the current work, a new method of technical creation was adopted, which involved the hybridization of two methods of technical creation: the diagram of ideas and the morphological matrix. The method used has a great informational reach and it increases the user's view in the field of interest. It outlines simple creation ideas by using independent morphological matrices. Also, ideas with a high degree of complexity are conceived because initially there are ideas from the morphological matrices of the three subdomains in the diagram of ideas that can be combined with the results/solutions of the matrices of another subdomain.

Technology can have a large number of applications in these sciences, biomimetics, and bionics. Thus, they can be created systems for exploring spaces that cannot be easily accessed or are almost impossible due to narrow access areas. For example, systems to save victims from earthquakes (under the ruins), medical imaging robots for patients' organs, biocompatible nanorobots, endoscopes that leverage vertebrate movement principles, etc.

The totality of these examples, resulting from the creative process, highlights only a few of the advantages that mankind can obtain by taking on/imitating ideas from nature, many areas integrating the perspective of biomimetics into the fundamental physicochemical principles.

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HIBRIDIZAREA METODELOR DE CREAȚIE TEHNICĂ ÎN BIONICĂ ȘI BIOMIMETICĂ

(Rezumat)

Este cunoscut un număr mare de metode de creație tehnică în procesul de ierarhizare a soluțiilor tehnice dintr-un domeniu de interes. Utilizarea independentă a acestor metode limitează capacitățile lor de a asigura acoperirea unor domenii largi, cum ar fi bionica sau biomimetica. În lucrarea de față, s-a propus combinarea a două astfel de metode clasice. Prima este metoda matricei morfologice prin care se poate ajunge la noi soluții de rezolvare a problemelor tehnice, iar alta este diagrama de idei care permite ierarhizarea și buna clasificare a soluțiilor generate. Astfel, hibridizarea celor două metode de creație tehnică a fost făcută pentru prima dată în această lucrare și poate fi un instrument util pentru inspirarea de la natură în procesul ordonat de soluționare a problemelor tehnice.