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BIOMIMETICS: NOTIONS, PROBLEMS AND TECHNOLOGIES

Biomimetics is an imitation model of systems and elements in the nature to solve complex human problems. Living organisms have well-adapted structures and materials for natural selection and have evolved over many years. The study of biomimetics technologies and their application in different areas can play an important role in the perfect economic development. This article touches upon various aspects of biomimetics and analyzes its technologies. The further development of these technologies in the future is intended.

BIOMIMETICS, TECHNOLOGY, BIOMIMETIC DESIGN, FLIGHT

Introduction

In the mid-20th century, a new scientific area began to form and was called “pattern recognition”. The main purpose of this scientific area was to determine the class which the recognized object belongs to. Objects close to each other for their features were classified [1]. As the “recognition of images” developed, other related areas began to emerge and develop. One of them is biomimetics.

Biomimetics driven from Greek word (bios-life, mimetis -imitation) is an imitation model of systems and elements in the nature to solve complex human problems [2]. Living organisms have emerged and developed from a well-adapted structure and materials for natural selection. Biomimetics has developed new technologies based on biological solutions of macro and nano scale. For example, in the early stages of the development of biomimetics, the structure of birds was well-studied for man to fly.

Biomimetics studies the biological systems and processes to apply the knowledge obtained from nature to solve technical issues. Biomimetics enables people to create original technical systems based on the ideas found and obtained in nature. Biomimetics proves that people’s inventions exist in living things, for example, hook and sticky fabric are invented based on bird’s feathers.

Biomimetics is closely related to biology, physics, chemistry, cybernetics, engineering sciences, electronics, and so forth.

Biomimetics studies the work of human brain and explores the mechanism of memory. It intensively explores the sense organs of animals and their responses to the environment (figure 1).

Fig. 1. Human brain

The main fields of Biomimetics studies primarily cover the following problems.

- Study of neural networks through human nervous system;
- Study of sense organs and perception system of living beings for the development of new sensors and detection systems;
- Study of orientation, location and navigation principles of various animals for their use in technical fields;
- Study of morphological, physiological and biochemical features of living organisms for the development of new technical and scientific ideas.

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One of the most famous examples of biomimetics is a human flight (figure 2).

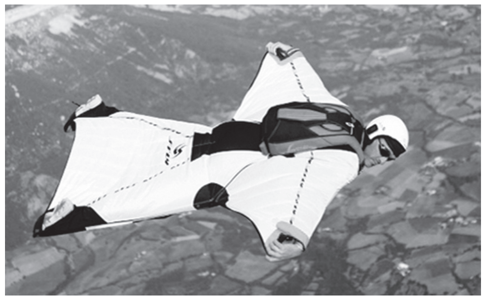

Fig. 2. Flying man

One of the most famous examples of biomimetics is a human flight. Leonardo da Vinci is known as the main challenger to design to carry out the first real research of birds’ and human flights in the 1480s. His famous original design, known as Ornithopter, had never been created, but was instructed to show the human potential to fly. His famous original design, known as Ornithopter, had never been created, but was instructed to show the human potential to fly.

Leonardo da Vinci (1452-1519) repeatedly observed birds' flight, describing them in his works (Figure 2), however he did not deal with that area. Although he was not able to create an "airplane," he was an observer interested in anatomy and bird's flight, and left numerous notes and sketches, as well as the sketches of "flying machines" [3] (figure 3).

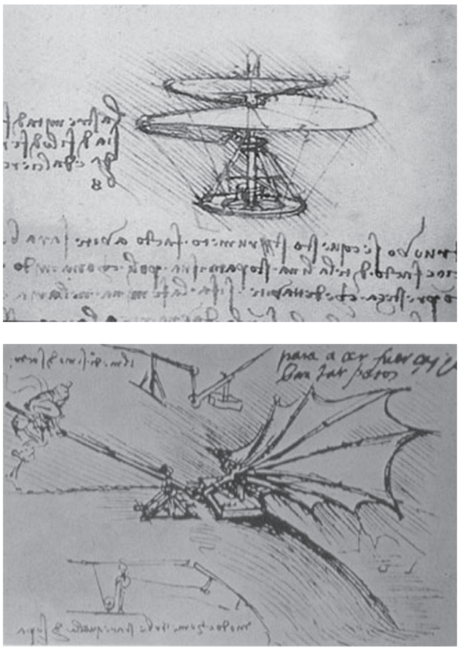

Fig. 3. Sketch of three-dimensional apparatus by Leonardo Da Vinci

In 1903, American engineers the Wright Brothers, who were able to take off the first heavy aircraft, were inspired by the pigeons in flight [4].

In 1950, American biophysics and polymath **Francis Otto Schmitt** developed the concept of biomimetics. He studied squid nerves in his doctoral thesis and attempted to develop a compatible biological nerve proliferation device [5].

1. Biomimetic design

Due to the consistent development of nature over the millennium, everything has its own solutions, and consequently, their use in solving modern human problems is being studied.

Despite the incredible inventive and engineering skills the humanity showed in the past millennium, as Pyramids, Skyscrapers, Supersonic Flight, people are constantly looking for the ways to develop new projects. Given the evolution in nature and millions of years of experiments and errors, taking advantage of the opportunities of nature is logical.

The areas of the biomimetics are shown in Figure 4.

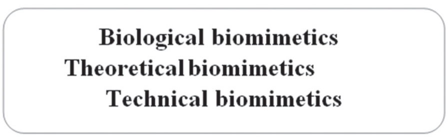

Fig. 4. The areas of the biomimetics

Biological biomimetics studies the processes related to biological systems.

Theoretical biomimetics builds the mathematical models of processes.

Technical biomimetics applies the theoretical biomimetic models to solve engineering problems.

2. Nature inspired biomimetics technology

One of the first examples of biomimetic materials is the invention of a widespread "sticky fabric". In recent years, the development of nanotechnology has stimulated the development of biomimetics.

Researchers have used different methods to imitate nature at the nanometric level. The goal was to create unique materials inspired by the natural samples. For example, a small lizard called gecko can adhere practically on any surface. To imitate the features of gecko, it was necessary to first understand the mechanism of the work of its pads. It was studied at the Nanotechnology Center in Manchester.

Some nature inspired technologies in biomimetics are given below (Figure 5).

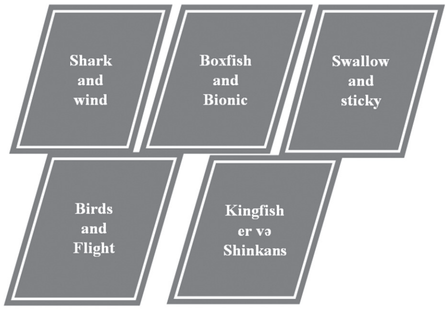

Fig.5. Some nature inspired technologies in biomimetics

Shark and wind turbines - Although the shark's weight is about 36 tones, it is one of the weakest swimmers in the sea. Bio-mechanic Frank Fish related the aerodynamic abilities of the bumpy protrusions on the front of its fins, called tubercles [6] (figure 6).

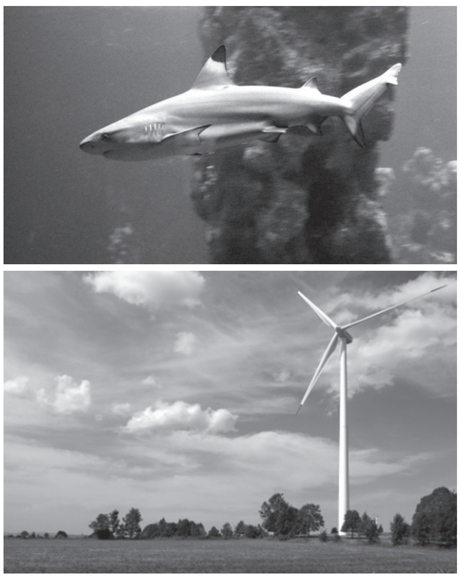

Fig. 6. Wind turbines and sharks

Boxfish and Bionic Car - Despite the huge appearance of the cube shaped boxfish, its resistance coefficient is approximately 0.06. For comparison, the coefficient of swimming penguins equals to 0.19. In 2005, Mercedes Benz developed the Bionic Car, inspired by the structure and gravity of cube shaped fish. It reduces the car's resistance, it has great rigidity and low weight, and uses less fuel than conventional cars (figure 7).

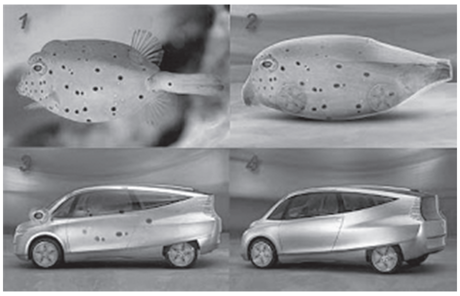

Fig. 7. Boxfish and Bionic Car

Swallow and sticky fabric - George de Mestral was inspired to invent the sticky fabric noticing how easy it was for swallow to stick to the dog's hair. Under the microscope, he realized the simplest design of small hooks at the end of the swallow's spines (figure 8).

Fig. 8. George de Mestral stick and swallow

Birds and Flight - One of the most popular examples of Biomimetics is a human flight. Several designers and engineers have been inspired by this concept, for example, German engineer Otto Lilienthal realized flights on over 2500 planes, nevertheless by 1903, the Wright brothers flew the first powered, heavier-than-air machine in a controlled and sustainable flight. This technology has led to the development of the 20th century and air industry technologies [6]:

Lotus inspired hydrophobia;
Water collecting beetles;
Biomimetic architecture;
Birds-safe glass;
Shark skin coat;
And so forth.

Kingfisher and Shinkansen. Japanese trains are famous for its incredible speed and efficiency. However, fast bullet trains driving out of tunnel at the speed of 300 km/h resulted in a strong sonic problem. The unfavorable outcome of sonic pollution caused by the change in air pressure was very alarming to the local population and attracted engineers to address this problem. Inspired by a kingfisher they solved this problem. Kingfisher are masters in traveling at a very high altitude both in air and water. Like Kingfisher, Shinkansen, a fast passenger train, is equipped with a long beak-shaped nose. This significantly

reduces the train noise, at the same time uses less than 15% of electricity and travels 10% faster than before (figure 9).

Fig. 9. Japanese fast train (Shinkansen) and Kingfisher

Bionic Bird - Drone - Bird. The biomimetic technology is used for drone to take off and fly faster without a pilot. Bionic Bird flies at a speed of 20 km/h and is controlled by a smartphone. Flights can be performed both indoors and outdoors within 12 minutes (figure 10).

Fig. 10. Bionic Bird drone - bird

The study of biomimetic robots and animal behavior is interrelated and inseparable. Through long-term evolutionary processes, animals have achieved natural advantages in movement, cognition, processing and control. Inspired by their development, the biomimetic robots, unlike others, have biological features that provide more powerful motion and cognitive ability and more sensitive control process. Simultaneously, the development of biomimetic technology and the mutual features of biomimetic robots also encourage studying animal behavior. This is a common representation of the relationship between biomimetic robots and animals' behavior. On the one hand, the role of the imitation of animals' behavior for the promotion of the development of biomimetic robots is illustrated in three aspects [7] (figure 11).

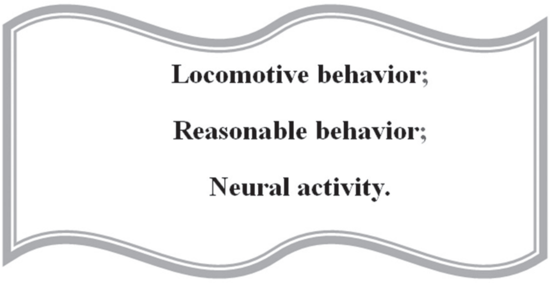

Fig. 11. Three aspects of the role of imitation of animals' behavior

On the other hand, the positive role of biomimetic robots in the study of animals' behavior is described in terms of behavioral responses, group behavioral mechanisms and cognitive-neurological activity of animals. In addition, the future development of biomimetic robots and the study of animals' behavior are discussed.

3. Biomimetics and software

[8] focuses on a preliminary assessment of the biomimetic diagram of a new form to simulate the function of human ear-hearing system (ESQ). ESQ consists of three parts: a pars-tensa and pars-flaccida, and its dynamic behavior, which, obviously, differs from other ordinary thin membranes. The developed membrane has a curved conical shape with an apex pointing medially, and with an initially bucked form. A small body also closely adheres to the medial surface of the membrane at its center. Additionally, TM is associated with a ring connection (mouse). Ultimately, the TM does not move as a straight flat or delicate diaphragm. In this study, bilinear nonlinear elliptical and conical shape, similar to the actual TM of the human hearing system, provided good vibration properties. When the Sound Pressure Level (SPL) is high, the adaptive diaphragm structure developed using the 3D printing technology, which can lead to 3D response frequency, may perform bilinear non-linearity [8].

When building the biomimetic neuronal structures, the topological features of biological neural networks are imitated on various scales. The optical technology platform is used for the reproduction of topological features of biological neural networks [9] (figure 12).

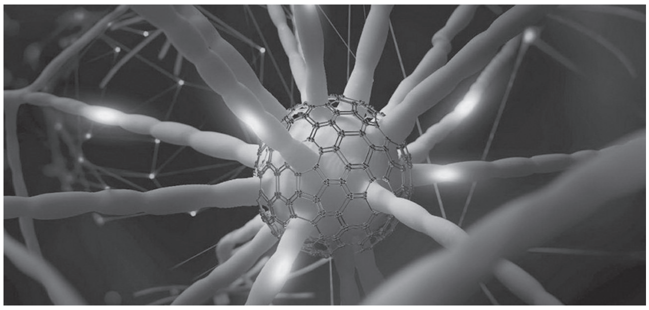

Fig. 12. Biomimetic neural structure

Autonomous submarines are completely or partly dependent on human decisions. The submarines should be equipped with special software to be independent. The main purpose of the program is to prevent the collision of submarines. In addition, the application should control various devices of the camera, such as the performance and interruption of cameras and so forth. The program is installed to the submarines' panel by the operator. Its task is to identify the submarines, disable the work, send emergency commands and remotely control the parameters. The goal of the software is to support the development and testing of other software components. In this regard, specific software is required to visualize all major facilities, the environment under the water and the submarines [10].

The project is proposed for the development of an interactive program that supports the test sequence and sensitivity of the program, which is based on the development models of the biomimetic system. Here, the prototypes are applied and evaluated. The system software specifies it and performs tests that detect errors [11].

Horseshoe bats (Rhinolophidae) differ from each other for the incoming and outgoing sound waves. In some studies, Horseshoe bats techniques are used to improve the coding of peripheral dynamic sensor data. The software architecture is based on MATLAB, which is a part of the flexible interface for experimental design and data analysis, while the server part is based on Python, LabVIEW [12].

Conclusion

Biomimetics introduces the principles and strategies interpreted from biological systems to engineering and technological designs [13].

Biomimetics is a field of research of strategy transfer from biology to technology, and has led to the emergence of important concepts in recent decades. The development of these technologies was illustrated by biomimetic processes consisting of several stages [14]. Some studies explored general descriptions and classifications of more than 40 technologies with quality criteria. The classification showed that certain stages of the process and their problems were finely solved by means of tools, while others were not solved. It can be concluded that the level of technology can be further enhanced, and the future theoretical and practical analysis is intended. These results can promote the widespread use of biomimetics [15].

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