BIONICS IN THE DESIGNING

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Abstract: *The bionics, an interdisciplinary science concentrates on the biological researches for solving the technical and technological problems. To bring into technical design the effects of bionic investigations a vast and direct cooperation of biologists and engineers is necessary. This difficult and complex problem is discussed in the paper. A generalized methodology and some propositions for solving the technical tasks in form of algorithms are proposed.*

1. INTRODUCTION

The dynamic development of the science and technique in the last time leads to the forming of many new disciplines. They are created on the peripheries of classic disciplines as mechanics, electrics, optics and develop rapidly. In this way the mechanotronics and elastooptics, were born. It corresponds to the contemporary trend to solve the complex constructive and technological problems in the group of specialists. The bionics belongs to these new domains too [3,5].

The bionics is an interdisciplinary science, concentrated on the biological researches for solving the technical and technological problems.

This new science was developed in the period from Norbert Wiener publications about cybernetics in 1948, to Jack Steele, who has proposed the name "bionics" in 1958. The fields of application of the bionics are very wide and differentiated.

The biomechanics, an important science investigating the human organism in order to design and implement the artificial organs and elements, developed as a branch of bionics.

As effect of biokinematic and biodynamic researches, many new solutions of mobile robots and prototypes of untypical units were constructed [7]. It is mainly the effect of studies on the way of movement of insects [4,12].

The biohydrodynamics opens the wide possibilities for the improvement of the swimming characteristics of submarines and other water vehicles.

New discoveries in the insect way of flying would probably solve in the future the problem of ornitopters and other untypical flying units.

Very intensive investigations of human brain and nervous system resulted in the conception and extensive usage of artificial neural networks in the expert systems and control. The genetic algorithms emerged from the biology too and now are widely used in technical design.

This indicate that the researches in the bionics may accelerate especially the development of the new, untypical solutions of machines, robots, mobile units and particularly the control methods, information perception and transfer.

The biological researches for mechanical domain and especially for machine building, should be carried out in the cooperation with the specialists, biologists and by means of exactly defined methods [9]. These cooperation in bionics should be more detaily considered and the necessary methodology should be developed.

2. BIONICS IN THE MACHINE BUILDING

The millions of years of evolution of the organisms on the earth resulted in immense number of different specimens, from primitive protozoa to the high developed primates and man. The activity of the evolutional forces may be compared with a giant laboratory of prototypes, with unlimited resources and time for researches. The created objects must undergo infinite changes and modifications caused by the change of life conditions or they will extinct. This results in the high degree of adaptation and perfection of the solutions occurring in the nature.

Observing the great differentiation of the living forms, it is difficult to believe, that their structure and activity are subjected to the rules and law, as the detailed investigations show, surprisingly convergent with these, in the machine design. They

concern the shape, functionality, material and transforming of information and energy.

The shape and structure of the organism are adapted to the way of living. The shape is resistant on the activity of external factors, and allows advisable localization of the muscles – power units. It is characterized by steady distribution of stretches, assured by shell or ribbed construction in which the bearing and supplementary functions are implemented. The principle of the optimal forming of the surface in relation to the volume is obligatory.

The functionality of the organism is usually expressed by the redundancy of the functions. The partial functions are mostly multiplied, there is the reoccurrence of the organs. The functions are often integrated when the organs are multifunctional.

The material is effectively utilized and resistant for the environment influence. The skeleton is almost in whole build from the sheet materials. Sometimes the structure forms the concentrations, ribs or spiral consolidations of the material in the places of the load. Most of the representatives of the animals world are the moving ones. The chemical principle of the muscles contraction is the same for all animals, but the way of moving and the moving organs are various.

The transfer of the information in form of the electro-chemical impulses in the neurons is the same too for all animals, but the nervous systems and receptors are very differentiated. The evolution presents all forms, from the simple neural networks of the Coelenterates to the most complicated brain and nervous system of the primates.

The foot-to-energy conversion system of the animals is very effective. Apart of the classic oxidant metabolism, the solar, electric and chemical energy is used. The organisms possessed the possibility of auto regulation of energy absorption by changing the surface, or position of the elements of the body.

The development of the machines is surprisingly similar to the evolution in the nature beyond of the limits of the time.

An existing machine, if it works satisfactory, is many times modernized and produced in new better versions. This discrete development is according to the demands of clients and market and can be realized a long time. Finally the last version appears and the production of the machine ceaseds. The technical progress, advances researches and investigations give the fundaments for a new, not always successful, solution. Sometimes a great importance have the unexpected innovations or discovery, which can fundamental change the actual conception of the designed object. The completely new solution is careful and exact verified in the experimental series and at last the new product appear on the market.

If the product is accepted, its life cycle repeats, its modernizations and ameliorations are implemented. In this way the evolution of the machine is in some degree similar to the evolution in the nature. The optimization of the construction may be considered as an evolution in the time as the answer to the changing environment conditions. Therefore the bionic investigation can be helpful in the designing process. This similarity is presented on the Fig.1.

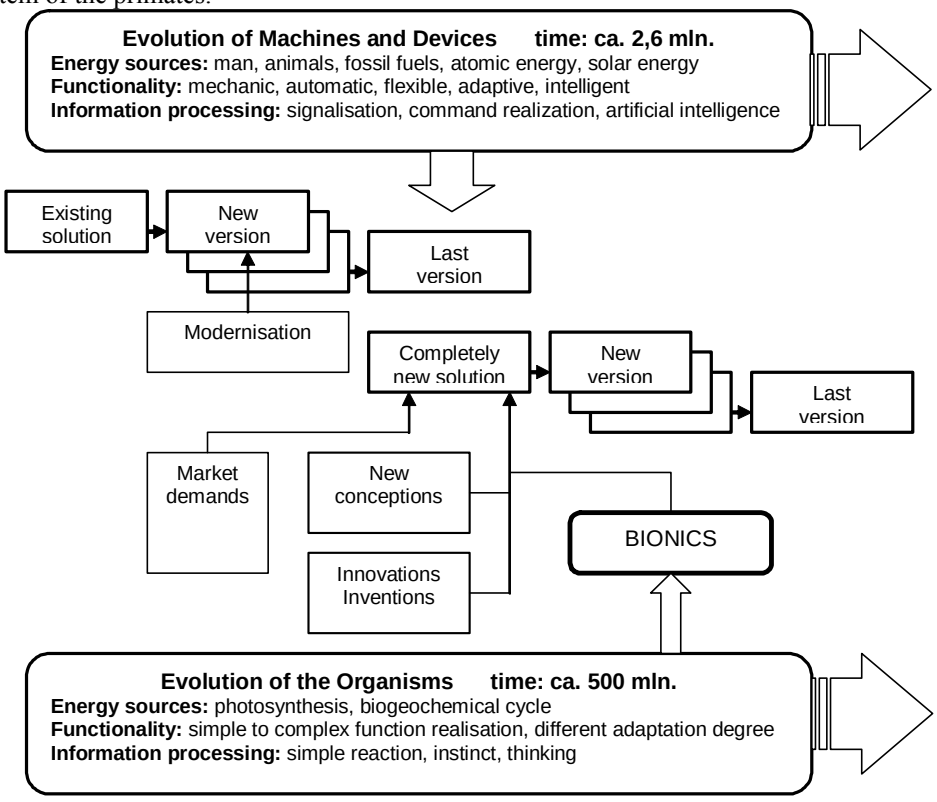

Fig.1. *Evolution in the machine building and the nature*

3. THE COOPERATING GROUPS OF BIOLOGISTS AND ENGINEERS

The cooperation of the specialists, necessary the bionic researches [10], necessitates reciprocal understanding of approaches and methods used by biologists and technical scientists. The lack of common language of definitions used by biologists and technicians may lead to the important difficulties in the bilateral investigations and interpretation of their results.
Generally the activity of an biologist may be characterized as follow:

- in the research work the descriptive methods are dominant. They refer to the structure feathers, behavior, and environment in which the given organism live,
- the dependences between structure and activity of the organisms are investigated and the general lows of the organisms life are formed,
- the changes of the organisms in the historical development and their evolutionary connection are researched,
- in general the deterministic and particularly mathematic description of features and functions of living object is not possible,
- the understanding of the technical problems, especially connected with construction and technology of machines and devices and the work methods in the industry is limited.

In turn, the engineers mentality and activity forms are completely others:

- in the investigations the analysis and synthesis methods are used, describing the occurring phenomenon on ground of physical, mechanical or chemical lows,
- the deterministic, mathematic description of characteristic and function of designed technical object is the fundamental principle of the activity,
- now and again the design of new machines and devices is founded on the just existing and proved solutions,
- the impossibility presentation of living forms as mathematical, physical or chemical models is difficult to accept,
- the knowledge of the forms and the richness of the species occurring in the nature is limited.

The mutual understanding of the characteristics of scientific activity of the other part and objective qualification of their results will be the guaranty of effectiveness of bilateral cooperation in the bionics. Depending on the complexity of the problem, the specialist groups may be differentiated and sometimes numerous. More often the necessity of the cooperation with highly specialized biologists as entomologist or ichthyologist is necessary. Sometimes solving technical problem gives the inspiration to the new unexpected biological investigation, or to the problem, which was till now not important from the biological point of view but can give completely new perspective for the technique [11].

4. THE DESIGNING WITH THE APPLICATIONS OF BIONICS

The basic method of approaching the problem is in form of a very general algorithm presented. The algorithm is divided into three parts and represents three design stages:

- definition of the designed object, description of the characteristics {C} and basic function (F) of the object, including all conditions and limitations. Distinction of partial functions {f}, and selection of the function (f), which is the subject of the biological research,
- analysis of analogous functions $\{f_o\}$ in the chosen groups of living organisms; determination of the similarity degree and detailed description of the realized function (f_o) in the chosen groups of organisms. This part of the researches is mainly realized by the cooperating biologists,
- synthesis of the described way of the function realization by the organisms. Building of simplified models of technical systems, which can serve as proposals of the construction solutions during farther design stages.

The first part of the algorithm is presented on the Fig.2.

It does not always happen, that a very complex object or its functions are investigated. Sometimes, the assumptions may be more simple and then, the searching of new solutions among living organisms does not require such laborious investigations [1]. Therefore three fields where solutions, coming from biological research are applied in technique, may be distinguished:

- modeling of a very complex object realizing a complex global function, with regard to the environmental conditions, the way of energy conversion and the given limitations. Then looking for organism realizing similar function is necessary and this investigations may be sometimes very difficult and expensive,
- modeling an unit or set of the technical object, realizing a relatively simple partial function, similar to this occurring in the nature, as catching, carrying or holding the pray,
- adaptation of a specific characteristic of the organism in order to use it as applicable technique. There are numerous examples: a claw shaped lock, different ways of animal camouflage, or the suppressing stratum of the dolphin's skin

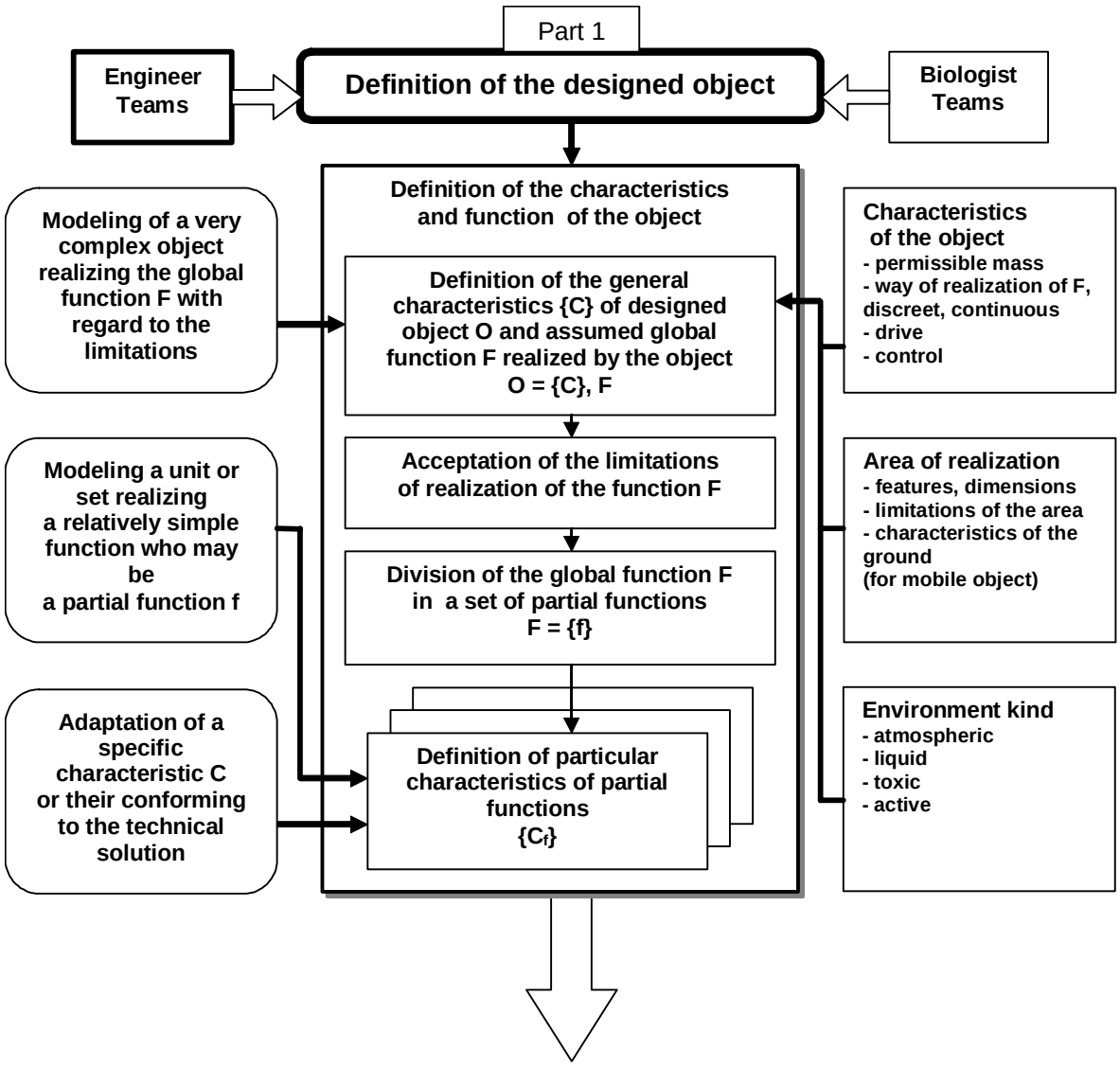

Fig. 2. *Part 1. Definition of the designed object*

The first and second fields of biological research application are particularly interesting not only in the machine building but in robotics too. First, before the development of the bionics, the main subjects of investigations were the higher vertebrates, i.e. the moving of the horse, or flying of the bird. Now the greatest interest is in the investigation of simple-structured organisms, the invertebrates, especially the arthropodan. An extraordinary richness of forms, and more simple analysis, allow to find aspects interesting for engineering and little known sources for inspirations. Among insects, crabs and spider, new, sometime surprising, solutions can be found. The results are mainly adapted to the mobile walking units especially in the mobile robots and units.

At this stage of design the fundamental activity belongs to the engineers. As the effect, they should present exact description of the selected function and demands which this function should fulfill.

The second part of the algorithm (fig.3.), the biological studies and searches is the main domain of the activity of the biologists. The main task of this fundamental part is the finding similar solution in the world of living organisms.

The analogy may concern the way of moving, structure of moving organs, control system, or environment conditions. After choosing some group, family or art the particular investigation are realized. The fundamental task of the detailed investigation is the description of the characteristic and function (f_o) realized by the selected organism. The investigations may be realized with different methods and testing equipment, according to the need, from simple observation of the activity of the organ, to the to filming using multi speed camera.

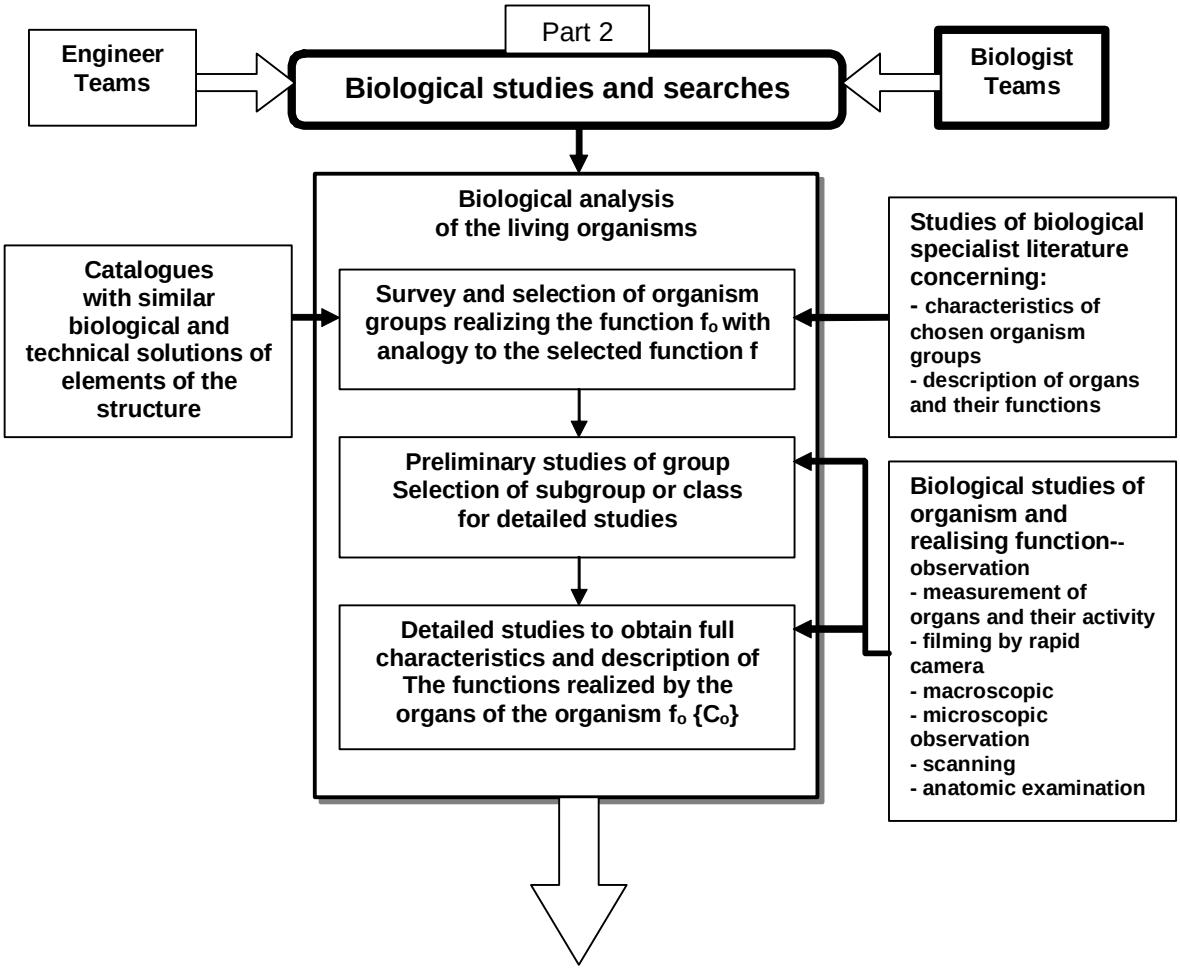

Fig. 3. *Part 2. Biological studies and searches*

The particularly knowledge about the structure of the organism give the anatomical studies using microscope or dissection. It is the fundamental domain of biologists activity and the participation of the engineers is limited to the control of the general investigation direction.

The third part of the algorithm, the synthesis, selection and model building, is presented on the Fig.4,

The task of this part of activities is the synthesis, description and building the simplified model of the technical object, fulfilling the demands and imitating the activity of organism on ground of the biological researches. In the comparison with the original, mostly the technical solution it seems to be very primitive. The simplifications are the effect, as well the lack of the possibility to use the adequate material, as the lack of obtain the effective energy transformation and the difficulties of control and limited possibilities of the communication with the environment.

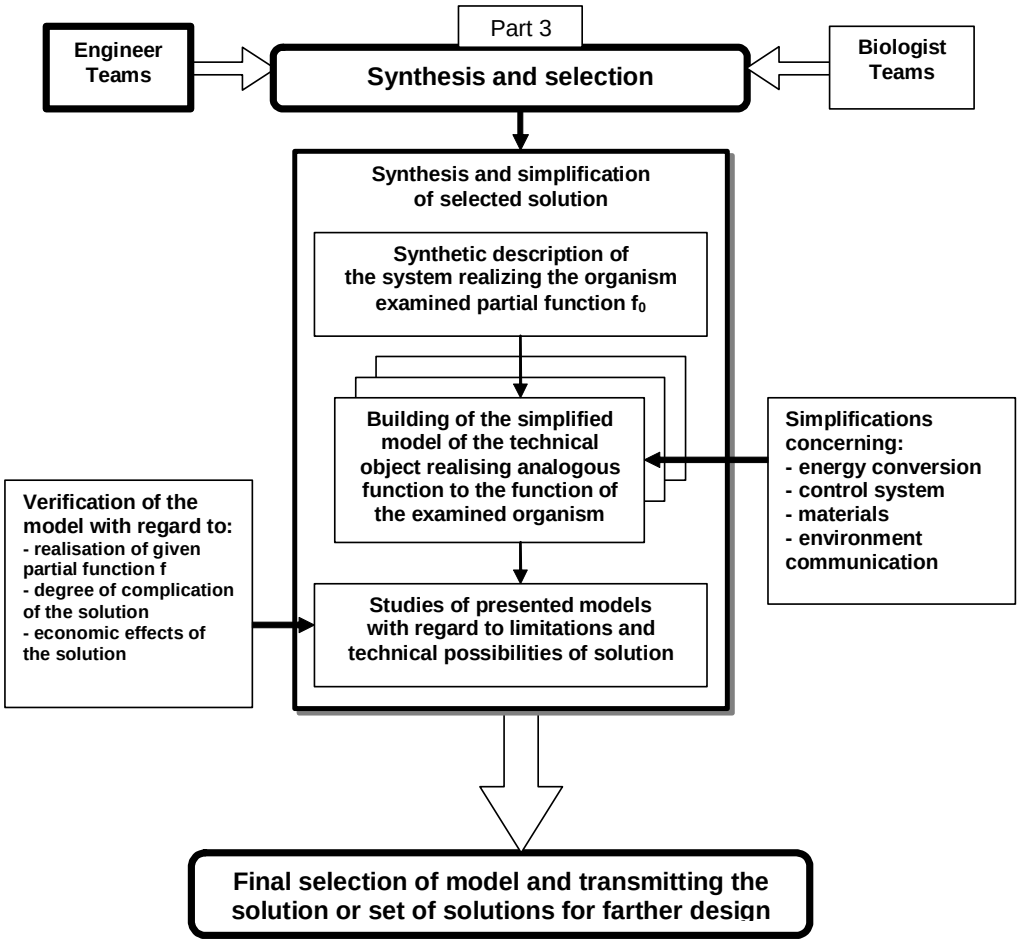

Fig. 4. *Part 3. Synthesis and selection*

Nevertheless, the model enrich the conceptions and give the inspiration and more possibilities to the selection of the solution. The simplified model or a set of models will be transferred to the farther design.

This is the fundamental goal of the cooperation of both teams, engineers and biologists and application of the bionic investigations in the technique, and one of the ways of the integration in the design procedures too.

As the result of the bionic researches many inventions and new unconventional innovations were developed. Many of them are now impossible for the realization, but they form a challenge for the future, form new ways and accelerate the technical progress.

5. CONCLUSIONS

The main conclusion from these short and very general considerations can be concluded as follow:

- the development of the machine building would take into account the features and characteristic of the biological systems, as redundancy of structures and functions, multifunctional organs, light sheet materials and efficient transfer of information,
- the application of the investigations in the bionics in the design demands a methodological approach, to obtain effective results,
- the direct cooperation of engineers and biologists is necessary. The reciprocal understanding, respect and common activities will be the guaranty for the success during solving of difficult problems with the bionic science.

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