LIVING NATURE AS A SOURCE OF IDEAS FOR NEW PRODUCT SOLUTIONS

DZĪVĀ DABA KĀ IDEJU AVOTS JAUNAS PRODUKCIJAS IZVEIDEI

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Abstract. *The future of enterprises depends among other things also on its rate of innovation. Particularly for the development of product ideas the innovation potential of living nature is used hardly or insufficiently during the construction process. Development teams orient themselves still too little at the evolution regularities and structure principles of biological systems. Orienting at the regularities of the evolution of biological systems as well as at the efficient principles of operation, structure and organization of living nature could supply various suggestions for new product ideas. For this reason the author of this contribution conceived a construction bionics, which helps the development engineer to use living nature systematically and purposefully as source of inspiration.*

Introduction

Among the about 40.000 announced inventions in Germany is also an increasingly rising number, which are to due to structures of biological systems. This "copying" of nature is not new, because from ever ago it already accompanied humans in their history of development.

The science bionics helps to get a way to important innovations, as for example the Velcro, the bulging nose of a ship, self-cleaning surfaces, riblet-foils for airplanes for fuel saving and many other things. But also with numerous, less spectacular inventions the animated nature served as a starting point for generating solution ideas.

Over three billion years of evolutionary nature processes brings out a streaming fullness of biological structures of almost difficult-to-understand diversity, which offer themselves as suggestions for organization for new products. The evolution as an universal self organization process, which brings out constantly new species, is an "inexhaustible source of innovation" and at the same time model for energy and material-saving technology.

Inventions of nature, used for the technology of humans, were already often starting point for the successful solution of technical problems. In addition, the human inventor spirit in many cases brought out technical solutions, which, as proved, already existed in nature for millions of years. Developing costs could be substantially reduced, if the technical designer would use living nature systematically as a source of idea (HILL 1998). Development teams (engineers, technical designers, designers...) orient themselves still too little at the evolution regularities and principles of biological systems. For example insufficient knowledge across biological systems and ecological connections leads the engineers to the fact that technology and nature are advised into a contrast. The reasons for the fact are, among other things, that appropriate information systems about biological structures in the construction process are not yet generally accessible and available. It is therefore suggested to strength the employment of strategically oriented proceedings and methodical means for the aim determination of technical development tasks and their solution identification on basis of bionic facts. With the solutions, which nature makes available "free of charge", the inspiration and creativity of an engineer can be increased. The central point crux in the construction process is to orient purposeful and systematic at the streaming fullness and variety of biological structures, brought out in millions of years of evolutionary nature processes and optimised on defined requirements, to derive promising solution types for future product generations. For this reason the author suggests establishing a construction bionics. The following remarks point out first attempts for the structuring of a construction bionics.

Systematic of construction and applied bionics as basis of the construction bionics

The systematic of construction is a methodological science for the solution of constructional problems. It covers the entire process of "finding" technical solutions, beginning with setting of tasks and its specifying, coming to the concept identification and the shape definition in the context of a draft up to the development of the final manufacturing and assembly documents with for use and disposal instructions of a product. HANSEN says substantial components of this process are regulations, which "are suitable to control this process rationally" (HANSEN 1974).

Because there is no clear allocation possibility of function and structure of a technical system, but always a multiplicity of different solution types for a technical problem, during designing there are no schematically or algorithmically processable steps sample as orientation help for thinking and acting, which by means of given information and security leads to the aim of a function-fulfilling structure. To that extent such a proceeding is rather a Heurism, which, paired with creativity and methods, makes a transition realization possible from one step to the next. For the solution trail there have to be generated function-fulfilling structures, which can be won over analogy formation. A possibility for the extension of the analogy search area exists in the use of biological structures to the solution identification (HILL 1998). Here starts the applied bionics[1]. At the beginning of our century OSTWALD (1986), EYTH (1908) FRANCÉ (1926) and others already employed themselves with methodical proceedings to the increase of effectiveness of the process cycle with solving technical problems. Among others HANSEN (1974), HERRIG (1986), KOLLER (1971), ROTH (1982), MÜLLER (1990), PAHL/BEITZ (1972), LINDE (1993) argued with the structuring of the process cycle by heuristically usable orientation models to the systematic of designing.

Bionics presupposes the modelling of biological systems for the purpose of the transmission on technical constructions. Fundamental method for this is the analogy formation[2]. In this connection the analogy width plays a crucial role, because it represents a measure for the originality of the analogy. The analogy formation and so the release of associations to the solution identification can be more effective, if the proceeding is systematically and purposefully and so creative free spaces will be created. For this purpose catalogs are conceived, which support the solution identification and lead the intuition in a solution- pregnant direction. On this way the technical designer receives a fast overview of possible structures and can select the most suitable solution for his problem. By the use of these association catalogs users of all technical branches have a rich arsenal of similar solution types for constructional problems to the choice. They are a solution-generating assistance and make by their employment a shortening of development times possible. With the help of the analogy method similarly functioning systems from nature are analysed and their structures abstracted, in order to uncover the underlying principle. This in such a way won principle can be turned into a suitable technical solution by variation and/or combination of structural components on the basis of to be carried out requirements, conditions and desires of technical-technological, economical, ecological and social character. Applied bionics and systematics of construction form the basis for a construction bionics.

[1] bionics as science discipline is concerned systematically with the technical conversion and the use of constructions, procedures and design philosophies of biological systems (NEUMANN 1993).

[2] on the basis of a function which can be realized technically, biological systems with similar functions are determined, operation characteristics are compared and afterwards the possibilities of a transmission of structural characteristics of the biological system for the anticipating technical system is examined.

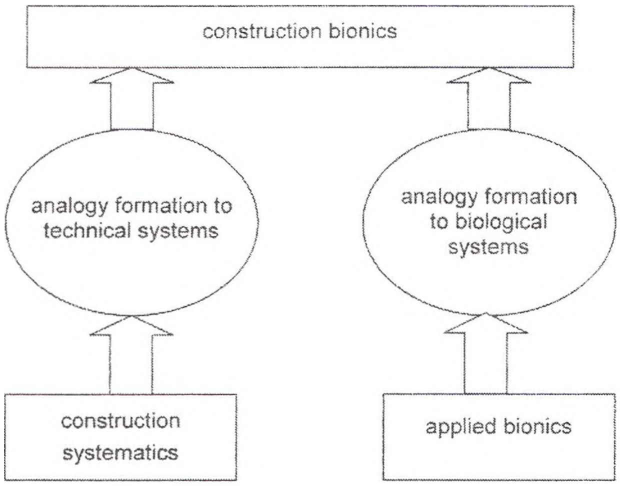

Fig.1. **Roots of the construction bionics**

The construction bionics uses the "patent arsenal" of living nature systematically and purposefully by using analogy formation. To this end the engineer can use memory systems for biological structure representations, in which he finds suggestions for the solution of technical problem definitions. A component of the construction bionics is a superordinated strategy model (signal element sequence / procedure), a method system, which serves the individual steps in the strategy model of transition realization as well as the above mentioned memory system of function-fulfilling bio structures.

Strategy model for aim determination and solution identification

Bionic thinking and acting integrated into the construction process can be described as a systematic way for the development of efficient technical solutions. In this respect this procedure bases on the necessary knowledge production for the nature-oriented possibility of forming of technology. Helping methods for the accomplishment of the individual steps and so for the successful overcoming of thinking barriers are assigned to the strategy model for aim determination and solution identification. The aim determination ends with the formulation of the task of development.

Goal setting for the use of evolutionary laws and contradiction

The creative transfer of the orientation function - technology using the directional analogy with the natural world - to current technological solutions (state of technology) makes it possible to a limited extent to view technology from the point of view of biological evolutionary laws. It is not about the direct transfer of these laws to the state of technology, but rather, about gaining stimuli for further development towards greater effectiveness and ecological efficiency. "The comparative analysis of biological and technical evolution has demonstrated the existence of many surprising analogies. We should not be surprised that these analogies can be traced back in part to the same evolutionary factors and laws." (Reichel, 1984).
Through the examination of analogy, the opportunity arises to transfer insights regarding heuristically useful laws which are abstractable and thereby open to comparison with technology. This makes it possible to define the future direction of development of the technological system being developed and to arrive at promising directions for solutions. We always therefore start from a point which embodies the most developed state of technology. The heuristic exploitation of evolutionary laws characterises the following representation.

Evolutionary laws also serve to find factors affecting effectiveness from the points of view of manufacturer and user, to confirm the developmental goals from the evolutionary point of view and to discern rough initial starting points for solutions (Linde / Hill, 1993).

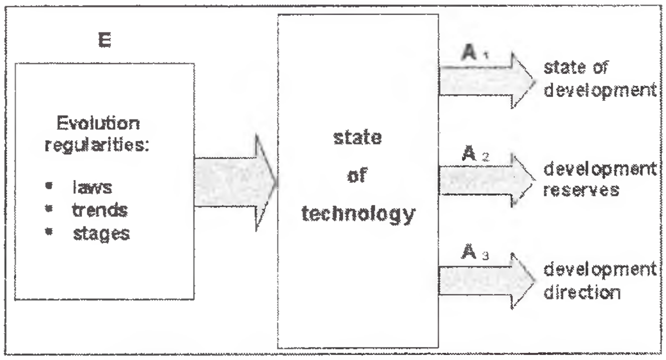

Fig.2. **Examination of evolutionary status**

Factors affecting effectiveness are technical-economic parameters, such as material and energy consumption, transport-economy, environmental friendliness, user-friendliness, assembly time, efficiency, reliability etc. These parameters should be considered from the points of view of both user and manufacturer. The basic aim is to raise the effectiveness of a system. This depends on the parameter xj described above.

$$E = f(x1, x2, x3, \ldots xn) \qquad (1)$$

Since the effectiveness of the system being developed is to be increased in comparison with the current state of technology, the values of the parameters show an increase.

$$E \uparrow = f(x1 \uparrow, x2 \uparrow, x3 \uparrow, \ldots xn \uparrow) \qquad (2)$$

Each effectiveness factor xj is in turn dependent on physical or geometric variables yk.

$$xj \uparrow = (yk \uparrow \text{ or } yk \downarrow) \qquad (3)$$

Using these physical or geometric parameters, contradictions between the requirements can be found from a table of requirements. Effectiveness factors are target values, which show positive increases and are directly connected to the directions of increase or decrease of the y system parameter.

Functional requirements for problem-solving are derived from the y system parameter. The functional requirements are assigned to the appropriate basic function (forming, transforming, storing, blocking, connecting, transferring of materials, energy and information). These provide the starting point for the determination of significant biological structures from the catalogues (see step 2.2 in the strategy model). These insights are demonstrated below by means of an example.

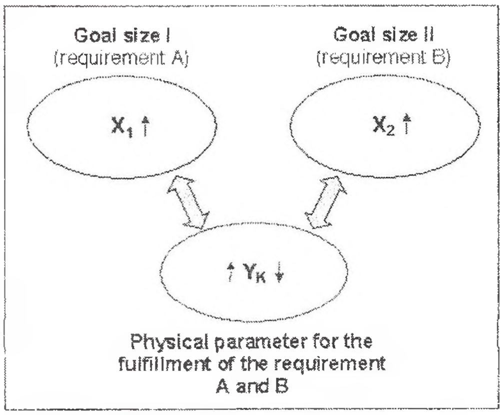

Fig.3. **Contradictions as core element of goal-setting**

Recognition, formulation and resolution of contradictions

Contradictions are uncovered by the human capacity for recognition in both the natural world and in technology. Ultimately, it comes down to increasing the effectiveness of the system. The effectiveness of biological structures is understood as the interrelationship between maximisation of the "survival function" and the related computed minimisation of energy use and biomass, with the survival function being designated as a complete function and including necessary sub-functions of reproduction, feeding, defence, movement, nest or burrow building, information capture, processing and transmission etc. This state of affairs represents a cost-benefit relationship which consists of keeping the cost in materials and energy in the carrying out of life-functions with regard to autogenesis as low as possible. Evolution often moves in the direction of higher effectiveness and it can be characterised by the effectiveness factors mentioned above such as reliability, stability, speed, sensitivity, tear-resistance, spatial requirements, energy use, use of materials, the ability to regenerate warmth etc. These "performance parameters" of biological systems are implemented through efficient structures. Through the effect of the evolution process, these structures are always constructed as well as they need to be and generally perform multiple functions 11 principle of multi-functionality. For this reason, a single effectiveness factor is rarely fully optimised. There can never be an absolute optimum, since certain life functions can change as a result of changing environmental conditions or adaptation to new habitats. For this reason, biological systems seek a phylogenetic compromise within the framework of the actual conditions and the totality of the environmental demands placed upon them.

For example, if a blade of grass becomes too long as a result of growth disorders, it will break. Although a longer blade of grass will be able to take in more sunlight than a shorter blade, since it would have a larger surface, it will be quicker to break under the effects of the wind. Here too, the evolutionary process tends towards a compromise between the contradictory pressures - a blade of grass which has sufficient length and effective resistance to kinking as a result of a good arrangement of materials.

There is therefore a contradiction between the actual prerequisites of achieving the goal of increasing effectiveness set and the actual unreliability of achieving this goal with these given prerequisites. That biological structures are suitable for the resolution of contradictions should not surprise us. Biological structures also fulfil contradictory requirements.

During the evolution of bears and the splitting off of the polar bear from the bear evolutionary tree, a contradiction can be recognised, which, through the action of the evolutionary process, has led to a more efficient structure of significance for the new habitat. The requirements of life in the new habitat were connected with increasing the amount of heat produced and a change in fur colour. A brown coat proved suitable for heat production, but unsuitable for melting into the white surroundings in the northern polar regions.

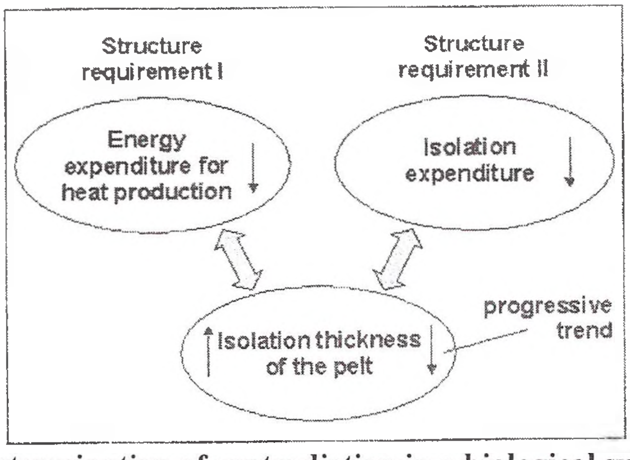

Fig.4. **Determination of contradiction in a biological system**

It the progressive trend which leads to minimisation of materials or to a maintenance of the same quantity of materials alongside a reduction in energy consumption in heat generation is followed, it can be seen that the difference in temperature between body temperature and body-like isolation chambers is slight. This is, however, only possible because polar bear hairs are hollow and serve as light channels, which allow the black skin to be warmed through absorption (resolution of contradiction).

The light channel system of the polar bear coat can be interpreted as a contradiction between the requirements of having a white coat for camouflage and simultaneously of using the available sunlight. These insights are stored in catalogue systems for problem-solving. Through the complete function storage, transferable structures are arrived at as a starting point for solutions for technical heat insulation systems.

Normal heat insulation systems are aimed at minimising heat loss through radiation from the buildings outer surface using insulating materials. On the basis of this understanding of the polar bear's skin and fur, transparent heat insulation (TUP) was developed. If this is defined as the state of technology, a low level of efficiency is recognizable.

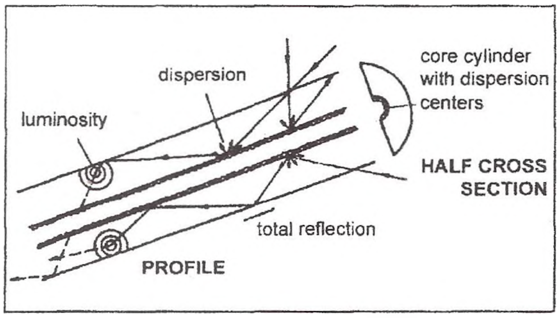

Fig.5. **Polar bear hair functions as a light channel with the sub-functions of light scattering, luminescence and total reflection** (after Tributsch, 1990)

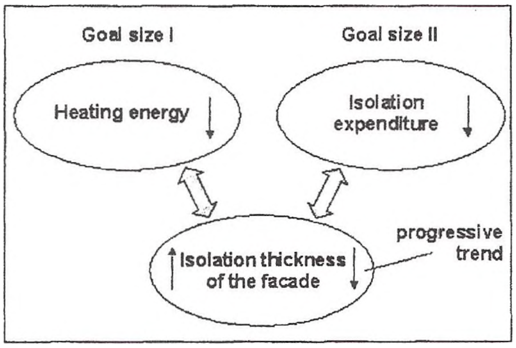

Fig.6. **Determination of contradictions, building facade** (with TUP)

For the amount of heat arises:

$Q = m \cdot c \cdot \Delta t$ (4)

With a higher temperature difference At between the ambient temperature and the temperature on the inside of the buildings outer surface, the expenditure for Q will be very large.

To resolve this contradiction, the integrated biological system of polar bear fur and skin was used as the basic solution for the systematic variation. The start point for a solution from the natural world could be reached through variation of the mechanism. Solar warmed water with a low temperature on the inside of the outer wall of buildings obstructs the transport of heat from the inside to the outside.

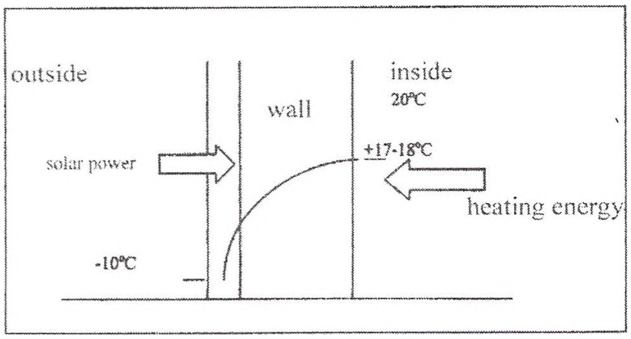

Fig.7. **Transparent heat insulation** (Stumpf I V0B, 2003)

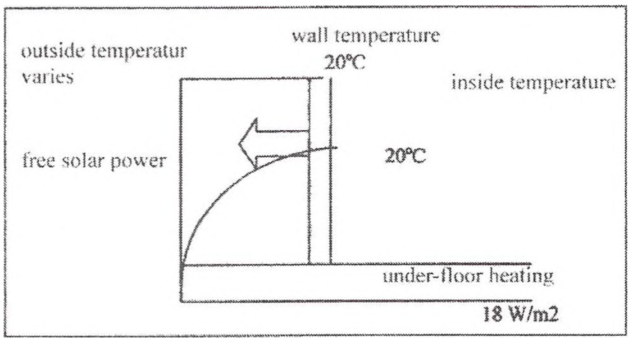

Fig.8. **Active heat insulation** (Stumpf I V0B, 2003)

At on the inside of the outer wall is very small and so, therefore, is the quantity of heating Q. Conductions of just 0.5 to 0.8 W!m2 of cooling area obstruct the transport of heat to the outside and allow a doubling of the duration of solar panel utilization.

The application of the nature-orientated innovation strategy with core elements of evolutionary laws and contradictions for goal-setting and solution catalogues yields new opportunities and possibilities for strategic product development. A bionic thought and action process as a general orientation model of bionics-orientated problem-solving can be inferred from these insights. The bionic thought and action process provides important stages of abstraction and actualisation, in order to generate the basic effective principle from the actual biological system and then to transfer these across to the relevant technical solution. This process is a component of steps 2.2 to 2.4 of problem-solving in the strategy model of the bionics- orientated construction for systematic and goal-orientated goal-setting and problem solving (see fig. 9).

In this model, goal-setting is of the utmost importance. Bio-strategic means of orientation in the form of catalogues of laws of biological evolution are used for the derivation of inventive tasks. It is also not about producing as many variant solutions as possible, but rather that the requirements for the task are made so exaggerated that contradictions which can lead to inventiveness in problem-solving become apparent.

With the help of the strategy model as a procedure the thought process, which is to lead to innovative solutions, is directed purposefully. By this procedure the technical designer organizes his thinking and acting and forms it more effective. By the supporting use of catalogues for aim determination with evolution regularities of the biological evolution and for solution identification with biological structure representations he can increase the imaginative power and promote his creativity at long last.

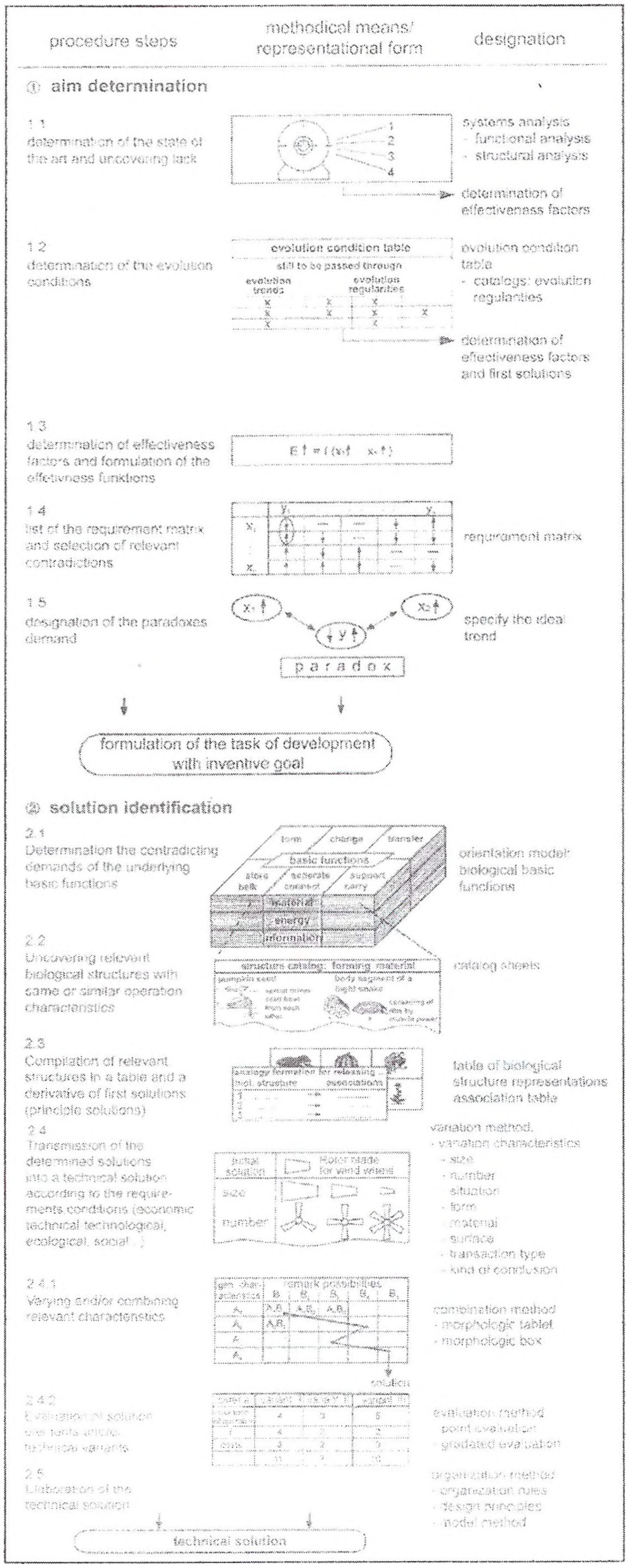

Fig. 9: Strategy model of the construction bionics

Structure catalogues for solution identification

Technology uses the functional analogy with living nature for solution identification. For the purpose of the systematic solution identification catalogues of biological structures are conceived and used. These support the solution identification. The biological structures are arranged according to the basic functions like forming, changing, transferring, storing/bulking, separating/connecting and supporting/carrying of material, energy and information. The search field for original solutions can be extended by the use of the basic functions. Because of the advantage of the higher degree of the abstraction of the basic functions, you are not bound to a special function.

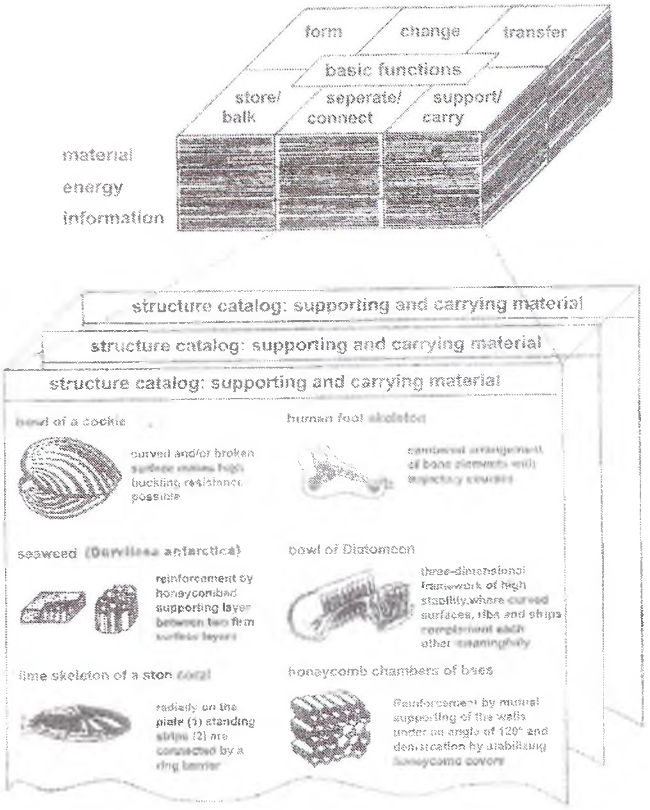

Fig.10. **Orientation model and catalogue sheets**

As above suggested, a technical function can be realised by different technical solution structures. For example in transmission teachings the technical function "producing a straight- line to and fro movement from a homogeneously rotating movement" can be realised by different kinds of transmission, like:

• swinging crank bow,
• push crank transmissions,
• sinus-wave generator,

and so on.

However these transmissions have different speed and acceleration conditions, the general characteristic to be able to transform rotary movement in straight-lined to and fro movement is all the same.

You can describe these transmissions as transmissions with similar functional characteristics, while all transmissions mentioned possess the characteristic of forming. If you idealise these characteristics and extend such principal functional connections on the basis of analogies, you reach the category of the technical basic functions. As technical basic functions we declare the abstractions of a class of technical functions, which call out same or similar effects.

By its high degree of generalisation each individual basic function includes a multiplicity of possible building groups as realization variants, without confining itself rashly on one building group only.

in animated nature similar conditions prevail. For example the tail fins of the fish produce the function of the propulsion during progressive movement (transferring). This can be achieved by different tail fin forms. The orientation model contains all necessary basic functions sorted after the organization characteristics material, energy and information. It represents an overview of usable basic functions and contains the appropriate catalogue sheets. In the catalogue sheets structure representations and operation characteristics of biological systems are shown, which are to serve for the release from associations for the solution identification.

The technical designer receives a fast overview of possible basic functions by the orientation model and can select the most suitable structures as the solutions for the available technical problem. Not at last the use of the strategy model and its catalogue system, full of far diversified suggestion potential, makes it possible to reach regularness, effectiveness, creativity increase and of course a shortening of product development times, also.

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