Design of Machines and Structures, Vol 4, No. 2 (2014) pp. 5–12.
https://doi.org/10.32972/dms.2014.012

STATISTICAL ANALYSIS OF NATURAL ANALOGY CATALOGUE

CSABA DÖMÖTÖR
University of Miskolc, Institute of Machine and Product Design
3515, Miskolc-Egyetemváros
machdcs@uni-miskolc.hu

Abstract: In the methodical machine designing the analogy based design methods are very important ways to reach the optimal solution of a particular problem. In such cases intuition is significant tool for engineers, which needs preexistent acquirements and experiences. Man knows for a long time past that the largest experience-collection is accumulated in the nature. This article will show how we can transform it to technical practice.
Keywords: *natural structures, bionics, biomimetics, design principles, natural adaptation, statistical analysis*

1. Introduction

In natural sciences there is a view, which has recently gained widespread acceptance, according to which finding the optimal solutions for technical problems in effect principles and effect carriers of the living and lifeless environment can be an efficiently adaptable option not only in research and development, but also in general engineering practice. This relatively new way of thinking has been justified by several products used in everyday life which show significant similarities with solutions in the living world.

For the rise of the application of natural analogies out of specialized fields it is inevitable for us to categorize, classify and teach them from an engineering aspect. The main findings of this paper reflect this effort, together with a database corresponding with an engineering approach and algorithms supporting its application which based on the well-known general problem solving model (*Figure 1*).

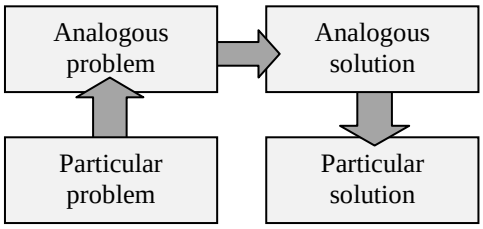


Figure 1. General problem solving model [1]

2. Directions of bionics

In the literatures of the science findings in bionics as well as biomimetics we differentiate between analogue and abstract procedures of natural adaptations [2]. In other sources analogue direction is called as “top-down” or “technology pull” procedure because analogue way starts from a particular technical problem and tries to find a special adaptable solution from nature (*Figure 2*) [10].



Figure 2. Main processes of analogue procedure [3]

In the steps of analogue procedure (*Figure 2*) it is easy to recognize the main stations of analogy based problem solving model (*Figure 1*) which useable for engineers long ago.

Abstract direction is a reverse process. At the same way to previously the alternative names of this are "bottom-up" or "biology push" procedure because in this case the starting base is a special biological effect and constructors try to find the potential employments of this and so create a new product. To reach this goal the abstraction gives the most important step of this process (*Figure 3*).



Figure 3. Main processes of abstractive procedure [3]

Essence of abstraction is that man able to explain occurrence over observation and in this way able to apply this experience in another field of science. How block diagram of analogue procedure shows similarity with general problem solving model likewise it is suggestive to sketch generalized model of abstraction (*Figure 4*) from the flow chart of abstractive procedure of natural adaptation (*Figure 3*) because it shows perfectly the different way of thinking which is based on diverse start-points.

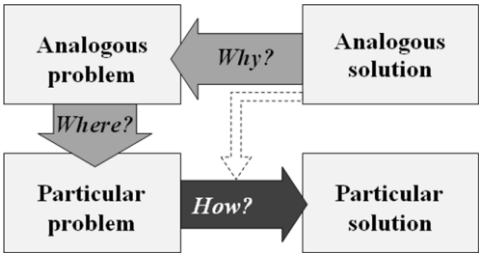


Figure 4. Generalized model of abstraction

The main steps of generalized model of abstraction are able to summarize with 3 short question-words:

Step 1: ***Why?***
Why must take it such as it is? In most cases it is recognizable the original problem or previous challenge which gives good base for abstraction.

Step 2: ***Where?***
Where could man use it? It is necessary to define a similar technical problem and recognize one or more realizable innovative employments.

Step 3: ***How?***
How could man realize it in a new product? The main mission is to develop a producible and saleable product with the mindful of technology possibilities and market conditions.

Relying on the natural analogy database this resource work is established that natural analogies account for 69% of the solutions in the analogue direction while the adaptations in an abstractive way account for 31%.

3. Catalogue of natural analogies

The main part of the research which shown in this paper is the classification of natural analogies according to engineering subfields as well as the presentation of their expressive examples, in which the two main groups are shapeforming elements and constructive solutions. As this paper cannot present analogies, data types and surfaces of the database are uploaded and shown in detail in Microsoft Access format and are available as electronic appendices. The computer-based analogy catalogue made it possible to categorize and analyze the detected similarities according to *content*, *direction* and – within it – *awareness*. On the basis of this taxonomy it is studied the complex data quantity of natural analogies from a new point of view and analyzed their positions in the design process.

3.1. Awareness as subcategory of two directions

Considering the records of the catalogue as being representative, it is realized that about 73% of natural analogies cannot be classified as the results of conscious search for an analogy. A part of these analogies is based on a *posterior recognition*, another part is the result of *spontaneous* matching of images in the designer's subconscious (*Figure 5*).

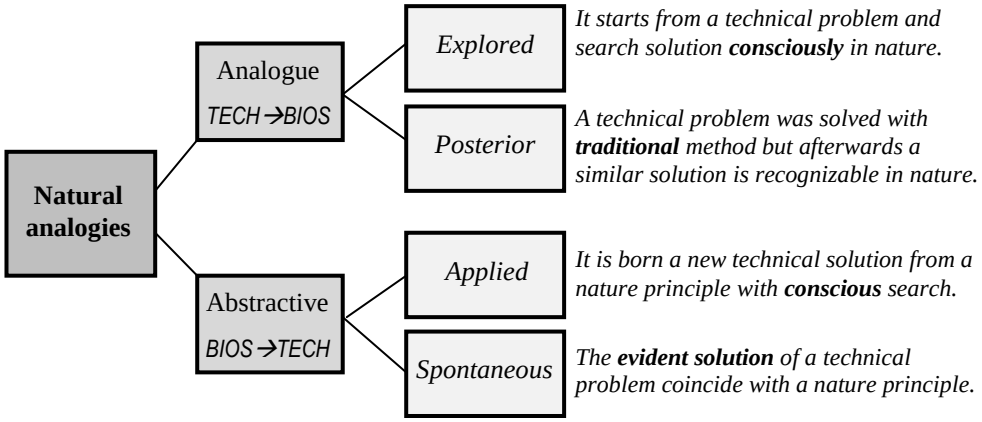


Figure 5. Directions of bionics and its subcategories [4]

3.2. Technical content levels

In analogy catalogue the classification of natural analogies according to technical content differentiate between three categories. These equally dispersed levels of *Theory*, *Form* and *Function* are realized in a hierarchy (*Figure 6*).

The depth of similarity can realize in 3 levels:

Level 1: **Analogy in Theory**

- The principle effect is the same between natural and technical solution, but the main function does not -or not unconditionally- show similarity.
  (e.g.: eye-spots → dummy security cameras)

Level 2: **Analogy in Form**

- There are recognizable essential geometrical similarities in effect carriers which realize the same principle in case of the technical and the organic example but from the point of view of final employing the performed function is not exactly the same.
  (e.g.: gecko → nanopad)

Level 3: **Analogy in Function**

- The two parts of natural analogy-pairs realize the same function and there are recognizable similarities in shape which attains the same basic principle.
  (e.g.: ears of the African elephant → cooler of cars)

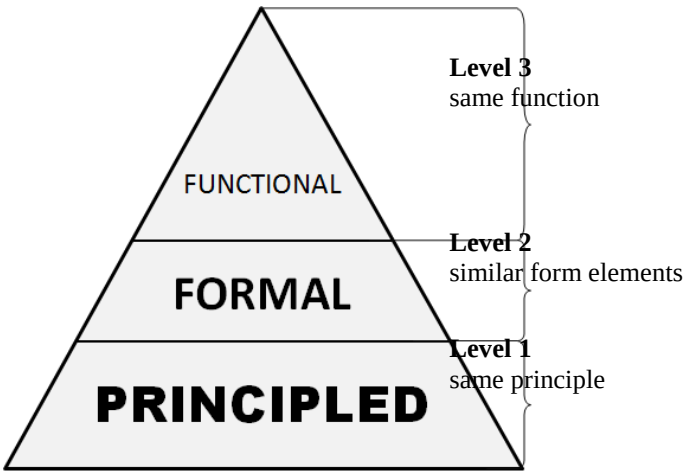


Figure 6. Hierarchy of technical content of natural analogies

On the basis of analysis of the records of natural analogy catalogue it is ascertainable that a natural adaptation is formal analogy only then the realized principle is also the same in technical and natural side. The functional analogies give the highest level of similarities where not only the principle effect and effect carriers are the same but realized final aim is harmonious too.

4. Algorithm

It is most important to integrate the similarities with nature into an existing analogy-based method. For this goal this paper presents the algorithms of processes called *Abstractive adaptation* and *Improvement* with well-known analogies on the basis of biological discoveries carrying special basic principles.

4.1. Algorithm for abstractive procedure

Starting from the generalized model of abstraction (*Figure 4*) it is worked out the algorithm of abstractive procedure of biomimetics that is showed in *Figure 7*.

4.2. Algorithm of improvement for analogue procedure

It is worked out the *algorithm of improvement with well-known natural analogies* (*Figure 8*). In this way it has proven that after the definition of environmental conditions and biological opportunities the *Posterior analogies* accounting for 66% of the database are suitable to improve and develop engineering pieces of work in a special way.

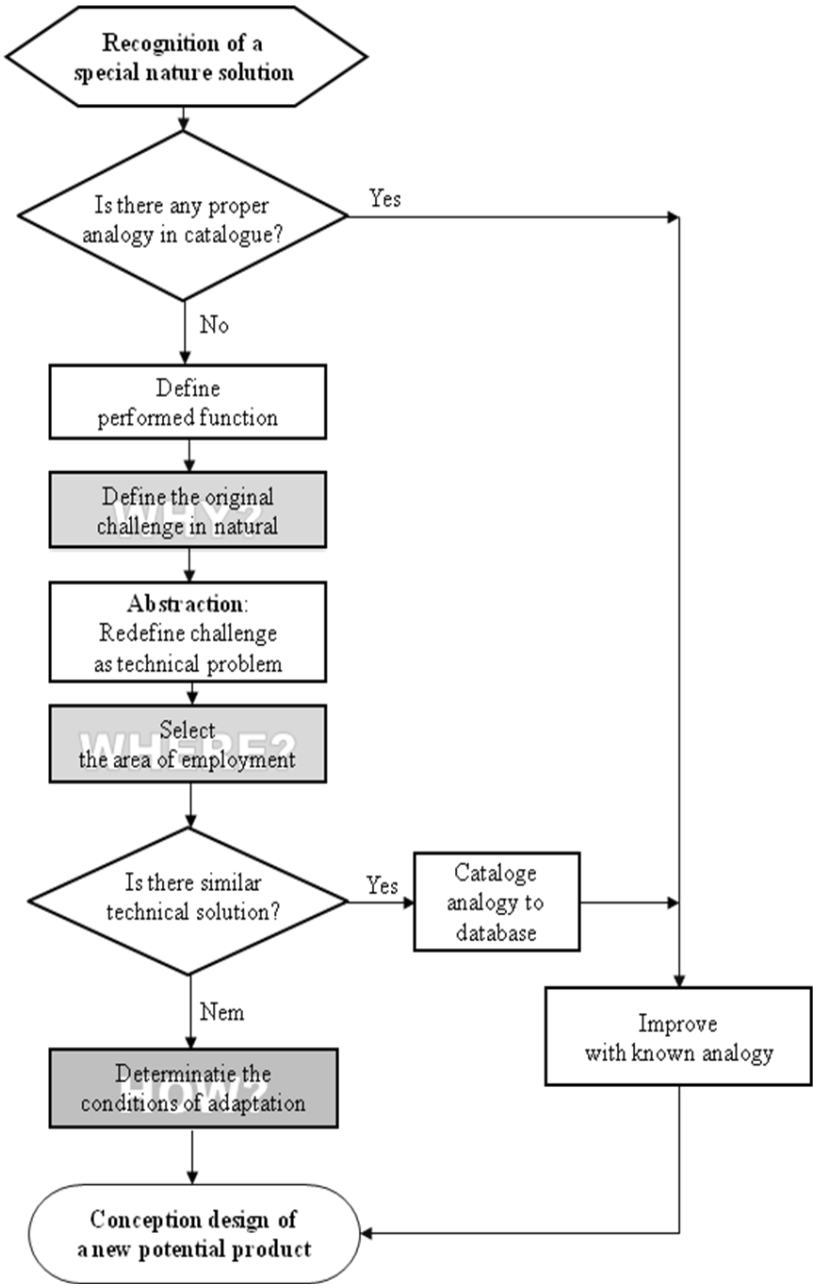


Figure 7. Algorithm for abstractive procedure

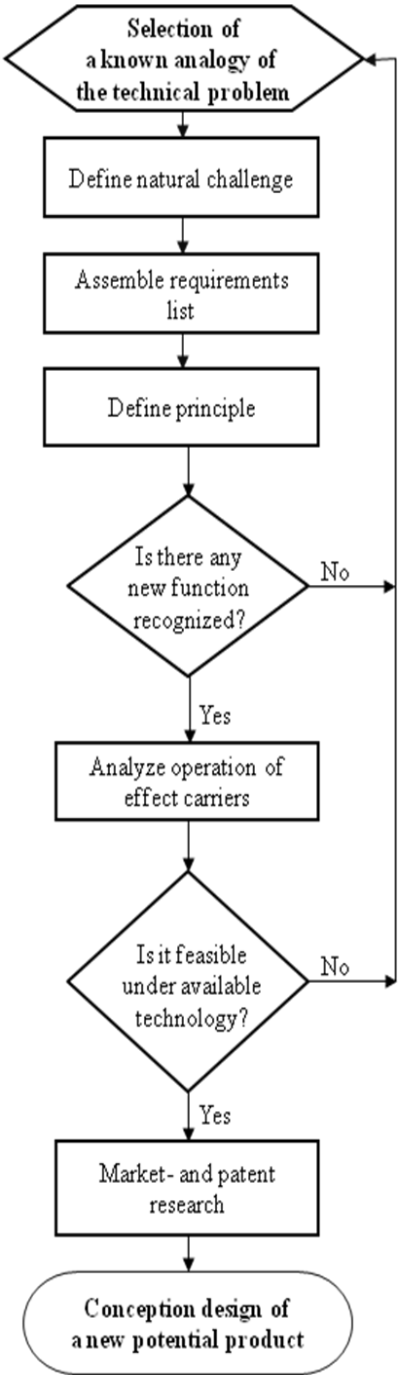


Figure 8. Algorithm of improvement for analogue procedure

5. Conclusions

On the basis of the findings it can clearly define the deficiencies that are the main obstacles of the application of the numerous solutions in nature. The described procedure is able to combine with the catalogue which possibility gives the theoretical basis for the computer-aided search for natural analogies and this way the application of natural principles in general engineering practice can become the permanent part of conceptual design process [11].

6. Acknowledgements

The research work presented in this paper based on the results achieved within the TÁMOP-4.2.1.B-10/2/KONV-2010-0001 project and carried out as part of the TÁMOP-4.1.1.C-12/1/KONV-2012-0002 "Cooperation between higher education, research institutes and automotive industry" project in the framework of the New Széchenyi Plan. The realization of this project is supported by the Hungarian Government, by the European Union, and co-financed by the European Social Fund.

7. References

[1] Mazur, G. H.: *Theory of Inventive Problem Solving (TRIZ)*. University of Michigan College of Engineering, 1995.
[2] VDI 6220: 2011-06 *Bionik; Konzeption und Strategie; Abgrenzung zwischen bionischen und konventionellen Verfahren/Produkten* (Biomemetics; Conception and strategy; Differences between bionic and conventional methods/products). Beuth Verlag, Berlin.
[3] Dömötör, Cs.: Natural motivations in engineering design. *Gép*, 2005 (56. évf.) 9-10. sz. pp. 5–26.
[4] Dömötör, Cs.: A természeti intuíció hatása a termékfejlesztés gyakorlatára. *Gép*, 2014, Vol. 65, No. 2, pp. 23–26.
[5] Benyus, J. M.: *Biomimicry: innovation inspired by nature.* Harper Perennial, 2002.
[6] Péter, J.–Dömötör, Cs.: Principles of the design theory and the nature. *XXVI. MicroCAD International Scientific Conference,* Miskolc, March 29–30, 2012.
[7] Péter, J.– Dömötör, Cs.: *Industrial design in development.* Miskolc-Egyetemváros, 2011.
[8] Pahl, G.–Beitz, W.: *Konstruktionslehre – Handbuch für Studium und Praxis*. Springer-Verlag, Berlin, 1981.
[9] Roth, K.: *Konstruiren mit Konstruktionskatalogen.* VEB Verlag Technik, Berlin, 1982.
[10] Nachtigall, W.: *Bionik: Grundlagen und Beispiele für Ingenieure und Naturwissenschaftler*. Springer, Berlin–Heidelberg, 2002.
[11] Takács Á.: *Termékek számítógéppel segített koncepcionális tervezési módszereinek kutatása*. PhD-értekezés, Miskolc-Egyetemváros, 2009.
[12] Hansen, F.: *Konstruktionssystematik – Grundlagen für eine allgemeine Konstruktionslehre.* VEB Verlag Technik, Berlin, 1965.
[13] Koller, R.: *Konstruktionslehre für den Maschienenbau*. Springer-Verlag, Berlin, 1985.