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The study on construction and application of knowledge base based on TRIZ and bionics

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Abstract. The TRIZ and bionics are two main methods to guide invention and innovation, which have universal guiding significance to product concept innovation. However, the function of TRIZ is more specific and not conducive to expansion. In this paper, TRIZ function is extended by reclassifying and defining TRIZ function. Then the extended functions and biological functions are combined to build a knowledge base combining TRIZ and bionics. Engineers can use this knowledge base to accurately match imitation sources. It also helps designers improve design efficiency. Finally, the feasibility of the biological instance library is verified by the rib design of the flap-like flaps.

1. Introduction

In the increasingly fierce market competition, whether to innovate products and meet customer needs timely is the key to business survival[1]. Conceptual design is the initial stage of product design, which can best embody innovation in the product design process[2]. The key to innovation is to use unconventional methods to obtain the novel design solutions. Therefore, an effective and practical innovation strategy plays an important role in the acquisition of innovative solutions. TRIZ and bionics are two major methods to guide innovative design[3]. Bionics provide a theoretical basis that use the excellent evolutionary results of natural organisms to innovate. TRIZ enables innovative design to be found regularly and plays a significant role in creatively solving the problems of inventions[4].

Focusing on innovative approaches that combine bionics and TRIZ, foreign scholars Weaver et al. proposed using biological examples and technical examples to illustrate the two principles of solving physical contradictions and innovation principles. It provides a better inspiration for innovation[5]. Bogatyrev presented the algorithm for biomimetic engineering based on TRIZ to solve ecological problem [6-7]. Vandevenne et al. proposed an automated bionic design process that based on a patent database to determine product characteristics[8]. These features are matched with the characteristics of the organism as determined from the biological database, ultimately providing a biological solution. Baldossu et al. proposed a bionic database construction. but it did not give a specific biological database[9]. British Bath University research team created a library of some biological examples based on TRIZ [10].

The domestic scholar L Q Ren proposed a concept of multi-element coupled bionics[11]. Multi-element coupled bionics is a bionic that simulates the coupling and synergy of many factors in biology, which provides a theoretical basis for the construction of bionic databases. Hebei University of Technology W Liu et al. proposed the bionic design of multi-biological effects, which put forward the

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coding rules for the construction of multi-biological effect libraries[12-13]. But it did not give a specific multi-biological effect case library.

Although scholars currently carry out a series of innovative methods on the combination of TRIZ and bionics, they only combine the functions of TRIZ and bionics. Although some scholars proposed the construction of bionic instance databases, they failed to give concrete examples. It is greatly limits the efficiency of bionic design and does not fully exploit the advantages of TRIZ and bionics. For this reason, this paper proposes a new construction of Knowledge base based on the combination of TRIZ and bionics, and assists innovative design through the biological instance library. Finally, the feasibility of the biological instance library is verified by the rib design of the flap-like flaps.

2. Construction of knowledge base and design process model based on biological function effect

2.1. Knowledge Base Construction

The realization of the function is based on the occurrence of material, energy and signal exchange. By analyzing more than 2,500,000 high-level patents worldwide, the TRIZ summarizes the 30 common functions that needed to solve difficult problems. It also summarizes the physical, chemical, and geometric effects that required to achieve these 30 functions. The function of TRIZ is more specific and it is not suitable for the establishment of functional structure and the expansion of the biological function of knowledge base. Based on taxonomy and evolution theory, 30 kinds of function of TRIZ is classified, extended, redefined to establish standard feature set, which include operating and shunt sets as well as the corresponding biological and flow sets operation. As shown in Table 1 and Table 2. Through the search of biological data, websites, literature and based on the Asknature bio-platform, we summarize more than 1,000 bio-functional effects that match bio-operational sets to form a knowledge base. Some biological examples and implementation functions are shown in Table 3.

Table 1. Engineering and biological operations sets.

Class operation	Basic operation	Biological operation
produce	compound, produce	compound, produce
change	increase, decrease, change, disguise, shape, control	improve, strengthen, multiply, transform, control
combine	mixing, embedding, assembling, link	embedding, mixing
separate	separate, decompose, extract	decomposition, differentiation, spread
gather	absorb, store, aggregate	absorption, Storage, Aggregation, Polymerization
movement	move, transfer, rotate, vibrate, lift	move, transfer, creep
measure	detect, measure, measure	perceive, feel, detect
maintain	prevent, maintain, stabilize	cooperate, compete, feedback, regulate, stabilize
eliminate	damage, Removal	immune, clear, phagocytosis

Table 2. Stream set profile

Class flow	Substream
substance	solid, gas, liquid, organic, inorganic, mixture, polymer
energy	force, sound energy, light energy, electric energy, magnetic energy, gravity, deformation, thermal energy, mechanical energy
information	temperature signal, pressure, acoustic signal, light signal, electromagnetic signal, deformation, concentration, density, fluid, chemical signal, behaviour

Table 3. Part of the biological function effect example library

Function code	Realized function	Corresponding biological and biological effects
F1	measure temperature	Rattlesnake hunting by sensing prey temperature
		The giardia senses fire through infrared
F2	Reduce the temperature	Antelope cooling
		Whale cooling through tongue
F3	Detect object displacement and movement	Bats evade obstacles by emitting ultrasound
		Whales and dolphins detect prey through echo
		Rattlesnake hunting by sensing prey temperature
F4	Improve strength	Toucan improves mouth strength by crossing bones
		Hexagonal structure of honeycomb
		Leaf veins distributed to resist wind and rain
		Distribution of vein of flying insects

2.2. The building of design process

After hundreds of millions of years of evolution, living organisms have a variety of functional features that are highly adaptive to their living environment, which provides inspiration for us to innovative design. We start with the TRIZ scientific effect to solve the problem of invention, and introduce the biological effect function into the functional design process. The functional design process is constructed based on the combination of TRIZ scientific effects and biological functions.

The product design process has the following steps; As shown in Figure 1

Step 1: Preliminary analysis of demand issues. According to the existing product situation and combined with the user's needs, we determine the total product features and then define the function. The function is generally defined in the form of “verb+noun”.

Step 2: Biological function effect instance query. We can match the biological instances or biological effects through the common operation set in the biological instance library. According to the simple biological instance query system, relevant biological instance information can be accurately found. For example, an electric fan needs to have as little sound as possible during operation, so this function can be defined as “lower + noise”. Through the biological instance query system, the long-eared, near-silent flight function can be found. After analysis, the shape of long-eared beak wings can be used as a fan-like noise reduction bionic model. Thus, the feasibility of the scheme is verified.

Step 3: Bionic design. We analyze the structure of the bionic mold and establishes the extension model, then carries on the bionic design.

Step 4: Bionic program evaluation. Finally, the bionic scheme is evaluated from different perspectives. If it is not satisfied, it returns to step 1.

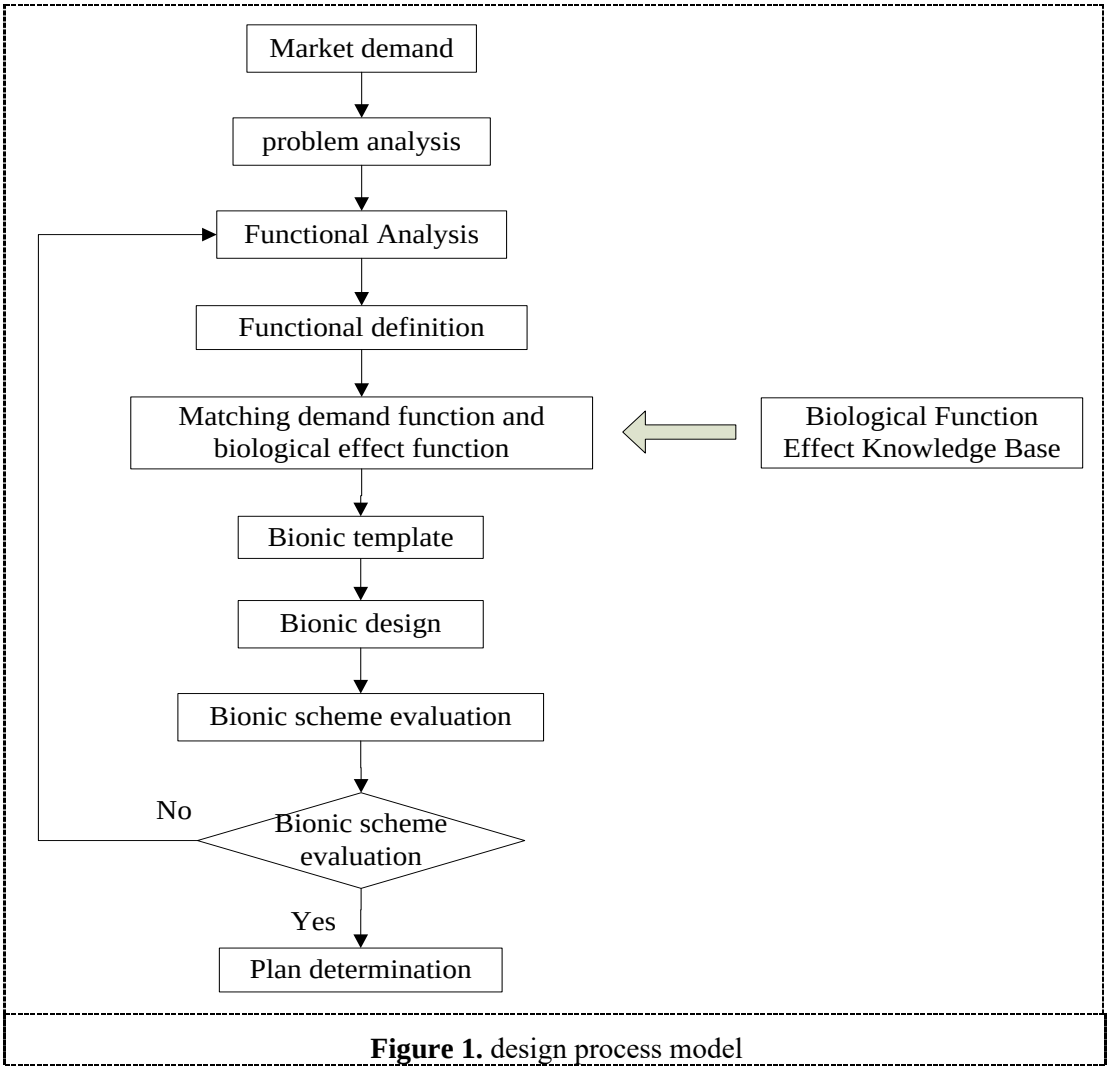


Figure 1. design process model

3. Design example

Step 1: Preliminary analysis of demand issues. Thin-walled sheet metal structures have a large number of applications in engineering, such as shipbuilding, aerospace, and automobile manufacturing. According to statistics, all types of reinforcements account for 30% of all parts of the ship. The distribution of reinforcement is very important. It is always a difficult problem for designers to realize product lightweight and maximum carrying capacity.

Step 2: Biological function effect instance query. The layout of stiffeners is actually to increase the strength of the product on the basis of material savings. This can be defined as increasing the strength by simplifying the demand function. According to the goal of increasing the strength, we can clearly query related biological examples in the query system. The result is shown in Figure 2. Based on empirical analysis and manufacturability, we chose the distribution of the cicada vein as a bionic object.

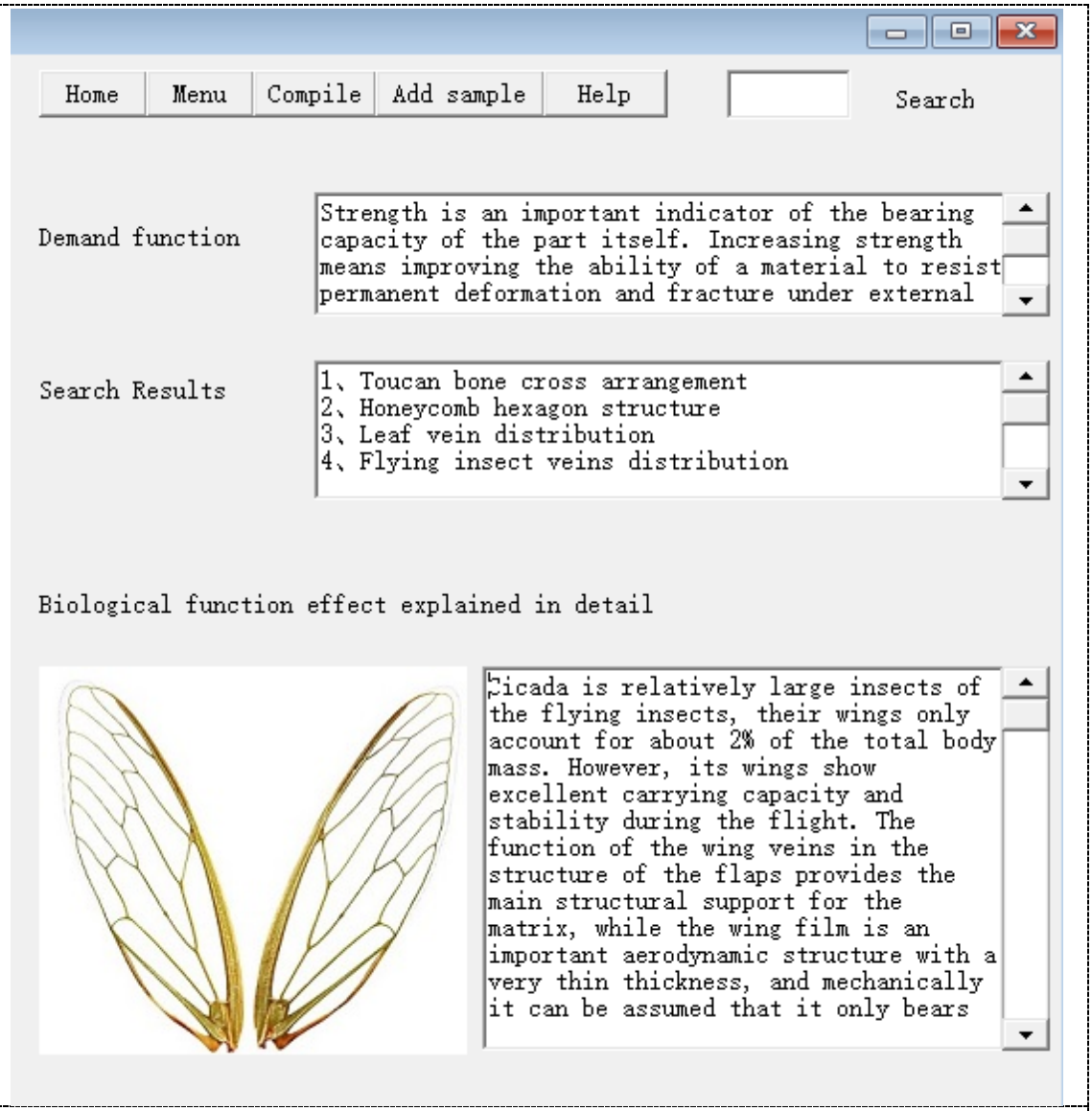


Figure 2. Bionic instance query results.



Figure 3. cicada



Figure 4. distribution of the vein of cicada

Step 3: Bionic design. Cicada is a relatively large insect in flight insects, and its wings only account for about 2% of the total mass of the body. As shown in Figure 3 and Figure 4. However, its wings show excellent carrying capacity and stability during the flight. The role of the veins in the structure of the flaps provides the main structural support for the matrix.

We take a cast iron plate of 100×100mm and a thickness of 10mm as an example to perform three-dimensional model using Solidworks. Two sets of stiffener layout parts were obtained, one set of sheets for imitation flap reinforcement ribs, and the other set of traditional stiffener layout sheets. As shown in Figure 5 and Figure 6

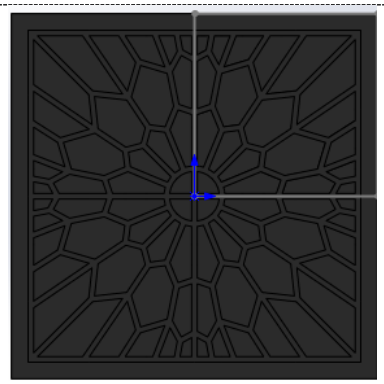


Figure 5. Bionic design



Figure 6. Traditional design

The bionic model and the traditional model are simulated and analysed respectively. The model is imported into solidworks simulation module. Static stress analysis is firstly selected to fix the bottom surface of the model. Simulation of the actual working environment, the model on the plane loading 10 KN uniform load. According to the actual demand, the model is divided into medium density grid. The simulation results are calculated by computer, as shown in Figure 7 and Figure 8.

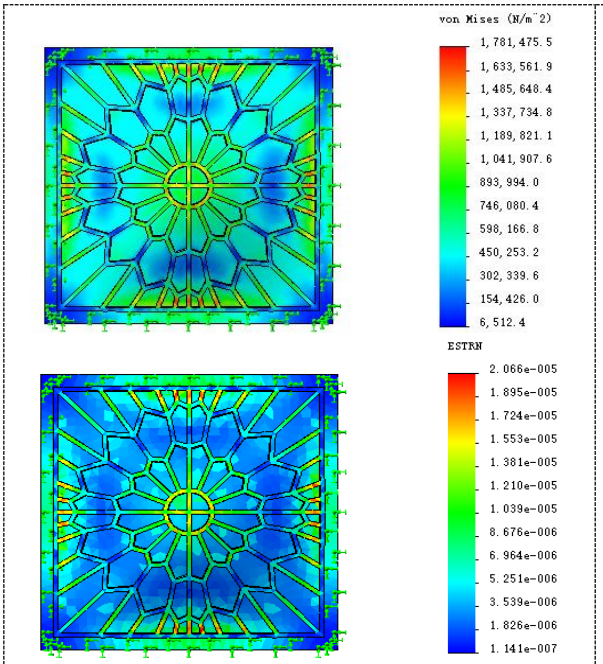


Figure 7. Traditional design simulation analysis results

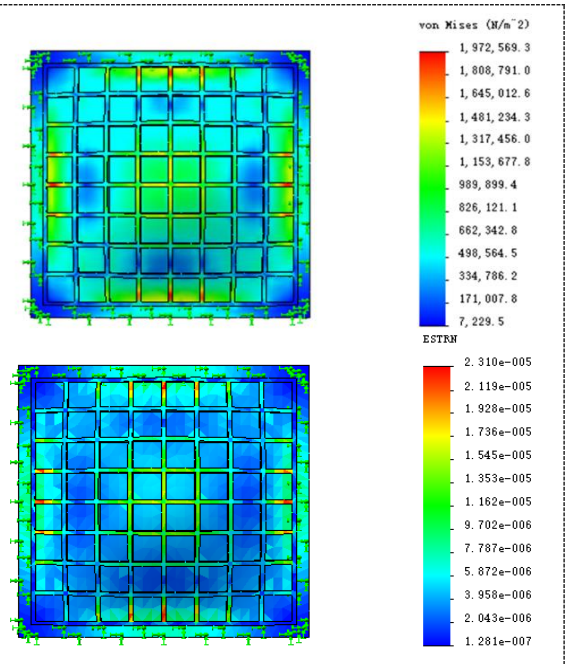


Figure 8. Bionic design simulation analysis results

Step 4: Bionic program evaluation. According to the simulation results show that under the same quality, the stress of bionic reinforced steel sheet decreases by 11.8% and the strain decreases by 10.7% compared with conventional reinforced steel sheet.

4. Conclusions

The introduction of biological function effect and the construction of corresponding knowledge base further enriched TRIZ scientific effect library. Compared with the original understanding of TRIZ, the innovative solutions provided by biological examples are more intuitive. Compared with bionic design, the construction of the bionic design process model can effectively shorten the time for designers to match biological examples, thus improving the efficiency of bionic design. With the development of artificial intelligence, it will be more convenient to combine biological knowledge base with artificial intelligence.

Acknowledgement

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References

[1] Benyus J M 2002 Biomimicry: Innovation Inspired by Nature[M]. (New York: Harper Collins Publishers Inc)
[2] Liu X M, Tan R H and Yao L G 2008 Application Research on Integrated Process Model for the Conceptual Design of Product Innovation *J. Chinese Journal of Mechanical Engineering* vol 44 pp 154–162
[3] Vincent J F, Bogatyreva O A and Bogatyrev N R 2006 Biomimetics: Its Practice and Theory *J Journal of the Royal Society Interface* Vol 3 pp471
[4] Chybowski L, Gawdzińska K, Przetakiewicz W. 2017 AHP based multi-criteria function analysis as a TRIZ tool for complex technical systems *J Proceedings of the 13th MATRIZ TRIZ fest 2017 International Conference.* September 14-16,
[5] Weaver J, Kleinke D 2010 Extending the TRIZ methodology to Connect Engineering Design Problems to Biological Solutions *J.*
[6] Bogatyrev N R., Bogatyreva O2012 TRIZ-based algorithm for biomimetic design *J. TRIZ Future2012,* p.251-262, Lisbon, Portugal
[7] Bogatyrev N R, Bogatyreva O 2013 Permaculture and TRIZ methodologies for cross-pollination between biology and engineering *J. TRIZ Future International Conference*, p83-90
[8] Vandevenne D, Verhaegen P A and Dewulf S 2015 Product and Organism Aspects for Scalable Systematic Biologically-Inspired Design *J. Procedia Engineering* Vol 131 pp784-791
[9] Baldussu A, Cascini G 2015 Integration Opportunities between TRIZ and Biomimetics for Inventive Design *J. Procedia Engineering* About Vol 131 pp3-13
[10] Vincent J F V, Bogatyreva O and Pahl A K 2010 Putting Biology into TRIZ: A Database of Biological Effects *J. Creativity & Innovation Management* Vol 14 pp66-72
[11] Ren L Q, Liang Y H 2009 Biological couplings: Classification and characteristic rules *J. Science in China* Vol52 pp2791-2800
[12] Liu W, Cao G Z and Tan R H 2016 Research on Measures to Technical Realization of Multi Biological Effects *J. Journal of Mechanical Engineering* Vol 52 pp 129 -140
[13] Liu W, Cao G Z and Tan R H 2016 Research on Method for Coding Muliti Biological Effects *J. Chinese Journal of Engineering Design* Vol 21 pp1-5