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Biomimetics — Image search engine

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Foreword

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This document was prepared by Technical Committee ISO/TC 266, *Biomimetics*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Biomimetics is the science and technology that develops new technologies by using ideas learned from observation and analysis of structures, functions, and production processes of living organisms or utilizes them in manufacturing. The term “biomimetics” was first used in the 1950s by the American neurophysiologist, Otto Schmitt.

From ancient times, humans have manufactured mimicking forms and structures that living organisms have and functions expressed by them. It is a well-known story that Leonardo da Vinci conceptualized flying machines through precise observation of birds in the Renaissance period. In the early eighteenth century, the French engineer Marc Brunel designed shield tunnelling, inspired by the observation that a shipworm uses its secretion to bore through timber and push the sawdust out behind it. Recently, shark skin-patterned high-speed swimwear has been developed, inspired by the skin texture of a shark to reduce water resistance. A mosquito inspired Seiji Aoyagi of the Faculty of Engineering Science, Kansai University, Japan, to develop a “microneedle” that reduces pain during a vaccination. These are all examples of biomimetics and how living organisms successfully resolve the challenges of manufacturing products or technologies. However, the relations between biology and engineering in these successful examples owe much to the abilities of the people behind the research. In recent years, informatics represented by big data or artificial intelligence has made remarkable progress and allows a large amount of texts or images to be analysed, was more difficult before due to the performance of computers. Therefore, the use of informatics will allow us to consider possibilities of various combinations beyond the abilities of humans. This also greatly enhances the possibility of biomimetics (see Figure 1).

Biomimetics — Image search engine

1 Scope

This document describes prototypes of the image search engine (ISE). It focuses on the use and value of ISE, but also describes its design principles.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TR 23845, *Biomimetics — Ontology-Enhanced Thesaurus (OET) for biomimetics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 23845 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
data
minimum piece of information that is meaningful for its potential reader or user

Note 1 to entry: In many cases, data is a component of a larger entity, a data set or a database. Data can be text, e.g. research papers, simulation models, algorithms, numbers, pictures, figures, voice and video recordings.

3.2
database
set of almost any digital objects, e.g. text, picture, sound, video

3.3
image retrieval system
computer system used for browsing, searching and retrieving images from a large database of digital images

3.4
data retrieval
action of obtaining data from a Database Management System (DBMS) such as an Operational Database Management System (ODBMS)

3.5
ontology
formal, structured, and explicit description of concepts in a domain of discourse and the relations between them in the fields of knowledge management and artificial intelligence

Note 1 to entry: An ontology together with a set of individual instances of classes constitutes a knowledge base.

3.6
thesaurus
list of words arranged in groups based on similarity of meaning

4 Biomimetics idea creation methods using informatics

4.1 General

Both an ontology-enhanced thesaurus (OET)[2] and bio-theory of inventive problem solving (Bio-TRIZ, described in 4.3)[3][4][5] have been proposed as biomimetics idea creation methods using informatics. In an OET, a basis for collaboration among different fields, the language gap between biology and engineering is solved by ontology. This enables the association of things that have never been connected because of the difference of the words as these words have the same meaning. Bio-TRIZ is a database that supports the creation of ideas for patents mimicking living organisms by using TRIZ. While these methods focus on text analysis in informatics, this document focuses on image analysis. This clause discusses a biomimetics similarity-based image retrieval system subject to a scanning electron microscope (SEM) image database and the outlines these methods.

4.2 Ontology-enhanced thesaurus (OET)

In order to develop knowledge infrastructure as a basis for collaboration among different fields, consensus to tie knowledge of different fields needs to be standardized. More concretely, terms that tie knowledge of biology and engineering need to be defined in a thesaurus. To this end, an ontology to define, organize, and describe hierarchical structures and relations of concepts and languages of biology and engineering on biomimetics needs to be created. Japan's proposal of a "knowledge infrastructure of biomimetics" for international standardization aims to standardize processes to build a dictionary that can be shared in different fields by combining a method of ontology, which is developed by Riichiro Mizoguchi and his team at the Japan Advanced Institute of Science and Technology, as well as a thesaurus.[2] This allows the association of things that have never been connected because of the difference of words as they have the same meaning. ISO/TR 23845 describes prototypes of OET and the keyword explorer interface to OET.

4.3 Bio-TRIZ

TRIZ is a Russian acronym for Teoriya Resheniya Izobretatelskikh Zadatch ("Theory of solving inventive problems" or "Theory of inventive problems solving"). The TRIZ method is a category of a problem-solving method using a trade-off. Organisms evolve in response to changes in the environment by repeating trade-offs and acquiring new functions. Bio-TRIZ is a new concept created by Olga and Nikolaj Bogatyrev, designed to solve technical problems to bring high efficiency bio-functions found in nature into TRIZ's 40 problem-solving principles. Bio-TRIZ is being developed by Takeshi Yamauchi, from Niigata University and Hidetoshi Kobayashi, Osaka University. The creation of new technologies adapted for a lifestyle in a sustainable society has been under consideration by using Bio-TRIZ [3][4][5]. This is the database that supports the patent invention mimicking living organisms by using a theory of solving inventive problems. ISO/TR 23847 describes the application of TRIZ.

4.4 Biomimetics similarity-based image retrieval system

An image is information that directly drives inspiration. In particular, a sub-cellular sized electron microscope image is important in revealing structures and functions of living organisms and even supports the creation of various ideas in materials design. Through the optical microscope, an enlarged image of a sample, which is hit by light, is observed. For example, it is a limit that observes hair of 60 µm to 100 µm and lactic acid bacterium of around 10 µm. On the other hand, with the electron microscope, an electron beam is assigned to a sample in substitution for light and the sample is observed by enlarging the image. For example, observation of the structure of a virus around 100 nm or DNA around 1 nm is possible. "Associative Image Search" developed by Miki Haseyama, Hokkaido University, Japan[6] enables data in different fields to be retrieved without having specialized knowledge, through "image retrieval by images". This is what turns "tacit knowledge", knowledge based on biologists' experiences

or intuition that are difficult to verbalize, into “explicit knowledge”, knowledge that inspires creation of engineering ideas from a large amount of image information. This is a new data retrieval system that brings “inducing awareness and supporting idea creation” (see Figure 2). Implementing this retrieval engine enables us to inspire creation of ideas systematically without depending on “first thought” or “a discovery by chance”.

Explicit knowledge translates subjective knowledge into a language by a sentence and a figure in a target. In this case the word in the sentence or the figure can be assumed using a keyword search. Then, the information retrieval is based on using the search database of the existing keyword base. On the other hand, tacit knowledge is subjective knowledge based on personal past experience or knowledge that cannot become the language. In this case we cannot use the search database of the existing keyword base. The image of the creature includes so much information that it is difficult to take the explicit knowledge out of the image. Therefore, in the case of searching for the surface structure of the insect similar to the surface structure of a certain material, it is difficult for a material engineer to search the surface structure of a similar insect using the explicit knowledge of the surface structure of a certain material. However, if we can use the ISE, we can search the surface structure of the insect similarly to the surface structure of the certain material using the image of the surface structure of the certain material of which the explicit knowledge is known. Therefore, we can join the tacit knowledge of the surface structure of the insects together with the explicit knowledge of the surface structure of materials.

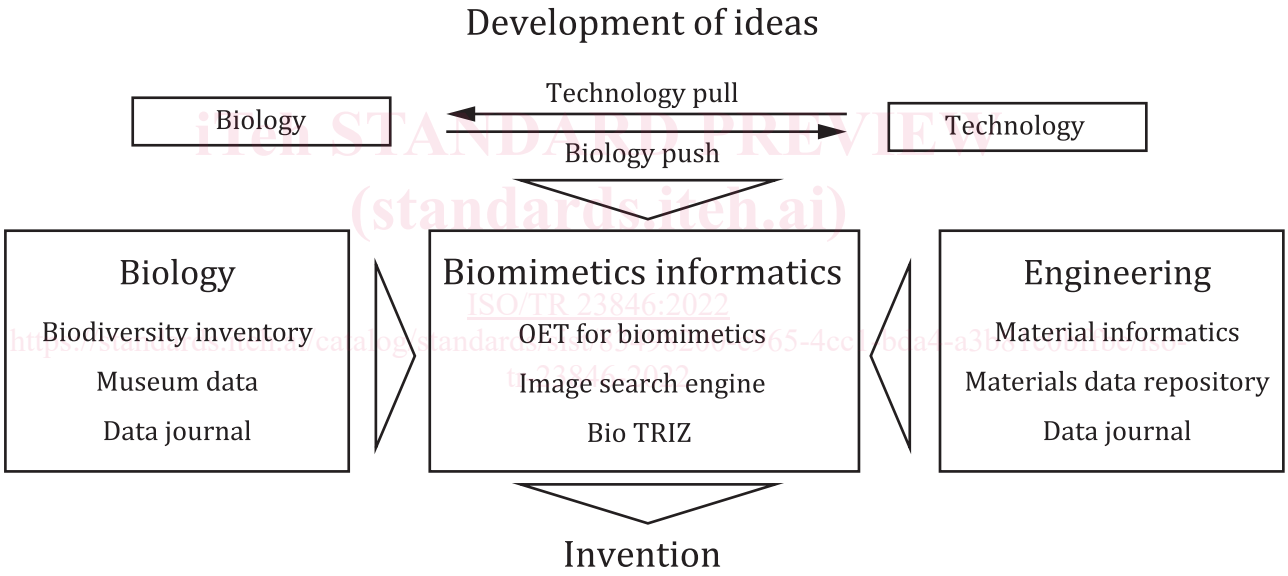

Figure 1 — Contemporary significance of biomimetics

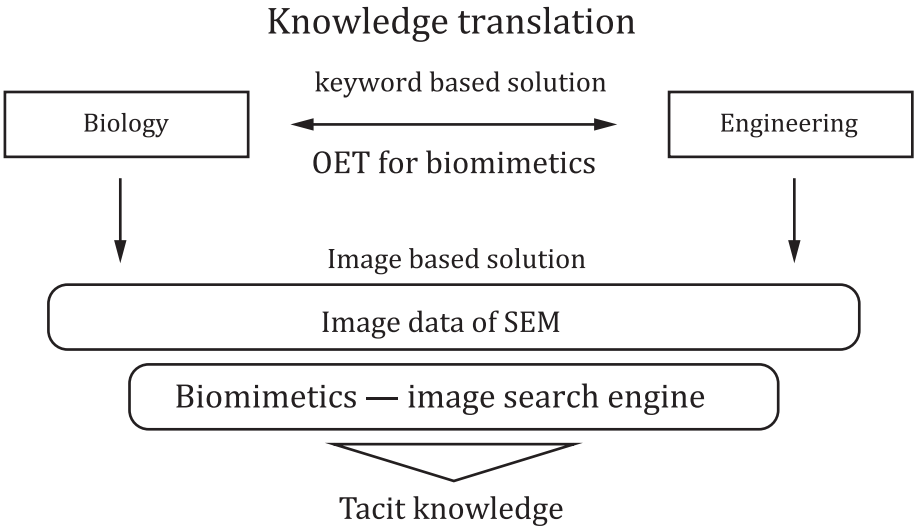

Figure 2 — Technology transfer from biology to engineering by information science

5 Background and concept of biomimetics similarity-based image retrieval system

A biomimetics similarity-based image retrieval system aims to lower barriers that prevent engineers from gaining biological knowledge and support creation of implementable ideas. This system provides new retrieval that supports idea creation by utilizing a large amount of image data included in biological databases, beyond the limit of conventional keyword retrieval. Image data stored in this system are images of a SEM, which has spread widely in this century. There are 9 900 images observing sub-cellular size structures of surfaces of insects, fish and birds. This system enables structures of various living organisms to be retrieved through images without having biological deep knowledge, because it is unnecessary to input a keyword. For example, the understanding of surface structures of living organisms or their functions by researchers in a wide range of studies, such as materials science or those who engage in developing technologies with using this system, leads to finding methods to solve their own problems in the process of development. This system allows the expectation of the new creation of manufacturing ideas.

6 Similarity-based image retrieval system

6.1 Retrieval from a large amount of image data

A biomimetics similarity-based image retrieval system is realized by an idea-creation support type retrieval theory. Similar images are automatically arranged near each other according to the similarity of images. By arranging as described above, from a large amount of image data that are impossible to check individually, the entire data can be grasped. Figure 3 shows an example of visualizing 125 SEM images of insects of the order *Coleoptera*. Although the size and family of the insect (1) are different from the insect (2), the microscope images of left middle legs show that their structures are similar. A biologist specializing in beetles expressed the opinion that these insects have come to have similar shapes as a result of having applied themselves to their habitats. In this document, the structural resemblance of the appearance is based on the hypothesis that it is similar to the function. It may not necessarily resemble it on a function side even if the structure of the appearance is similar. Therefore, it is just a purpose that searches the structural resemblance of the appearance, and the role of ISE does not search functional resemblance.