

Design by Analogy

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1 Introduction

Commonly, the function of analogies is linking a poorly understood situation with a well-understood one. [1] A method with analogy is suitable for solving a new problem that is lack of practical solution or sufficient information. [2] In Engineer design, capable of thinking in creative way and discover the problems with a fresh view is needed, and analogy is one good way to face the problems effectively. [2] The Fig.1.1 shows the basic steps of utilize analogy within the reasoning process. [3] The source often represents the knowledge of the people and external resources like database that people can gain and memorize at the first stage of reasoning. And then, retrieve the appropriate analog from memory, the sources that encoded. Typically, this is the most difficult part of analogizing. The next step is to find a connection between the design problem they are facing and the source analog. After this procedure, the design solutions are developed.

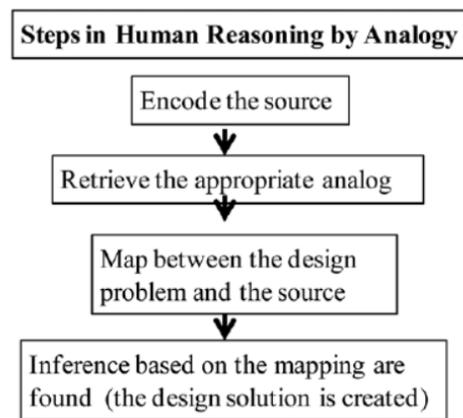


Fig.1.1 Steps in human reasoning by analogy

To utilize analogy into design, the concept of design by analogy (DbA) was presented, the main function of DbA is drawing and then converting elements from an existing solution for a design problem to the solution for the unsolved design problem. [4] DbA contains many contents nowadays, for instance, the method of Biomimicry, AskNature, Idea-inspire, WordTree, SCAMPER, Synectics, and Visual-Based methods are all DbA. To sort these methods, whether they are inspired by nature related elements can be a criterion. [4] In this report, we refer the two type of methods as BioX analogies and Non-Bio analogies. The former one is related with biology and nature while the latter one is not. The methods that covered in the report are Biomimicry and AskNature, Synectics, and WordTree methods.

2 BioX analogies

Considering the source of inspiration for the analogies, the methods inspired by nature, using terms such as bio-inspired, bio-mimetics and bionics. We aggregated these under the

term BioX analogies. This category comprises all methods that use nature, its principles, structures, functions, or behaviors as possible sources of analogy for mapping a given design problem characteristics/elements. There are several formal and informal BioX design approaches currently available; however, below we are describing one main structured formal method, Biomimicry.

2.1 Biomimicry and AskNature

Biomimicry comprises: a method, a taxonomy and a web-based tool, AskNature (<https://asknature.org/>). The drivers behind the analogical process of this approach are functions and physical principles.

The method requires a designer to define the context of the problem and identify functions. The designer then uses AskNature, the taxonomy, or both to find analogies. AskNature searches its database for examples of how nature fulfils the function identified by the designer.

Biomimetic design professionals need access to relevant biological information expressed in common language. Benyus and colleagues developed AskNature.org, which is a free, publicly available database of biological information and abstracts, in an effort to translate biological information so it would be accessible to non-biologists, and to serve as a source of inspiration for biomimetic design. [5]

Biological data on AskNature are from trained biologists and individuals, and all content must be approved by AskNature's content editor. Then, AskNature team began to look for patterns and to organize the data according to function. The result was a classification system call the Biomimicry Taxonomy, shown in Fig.2.1. The taxonomy categorizes strategies according to three levels: groups, subgroups, and function.

For example, an insect might face the challenge of protecting itself from other organisms that want to eat it. Its strategy to meet that challenge might appear like this within the taxonomy:

Group	Maintain physical integrity
Subgroup	Protect from biotic factors
Function	Protect from animals
Strategy	Nanoscale protrusions

AskNature consists of several components: biological strategy pages, biomimetic product case studies and a search engine.

All the biological content on AskNature is captured on strategy pages. Each strategy page consists of a carefully crafted title, a short sentence explaining the essence of the biological

strategy, the strategy's place within the Biomimicry Taxonomy, a scientific excerpt, biomimetic application ideas and/or links to biomimetic product pages, and links to scientific references via Google Scholar or Scirus. AskNature features biomimetic product pages for users to see how others have applied a certain strategy. For example, Fig. 2.2 shows users how one design group was inspired by the whitebark pine's spiral fibers to develop a distinctive, 100 % recyclable polyethylene terephthalate (PET) bottle. Searching is one of the most vital features on AskNature. There are numerous possible queries, but they must be plausible and recognizable by the database. For example, in Fig.2.3, if a user types in "build an airplane", the search may not return any useful results. After all, Nature does not build airplanes, but it is a genius at flight. If the user refines his search to look for things such as "generate lift" or "reduce drag"—that is, functions he would like his design to accomplish—chances are he will find much more relevant results.

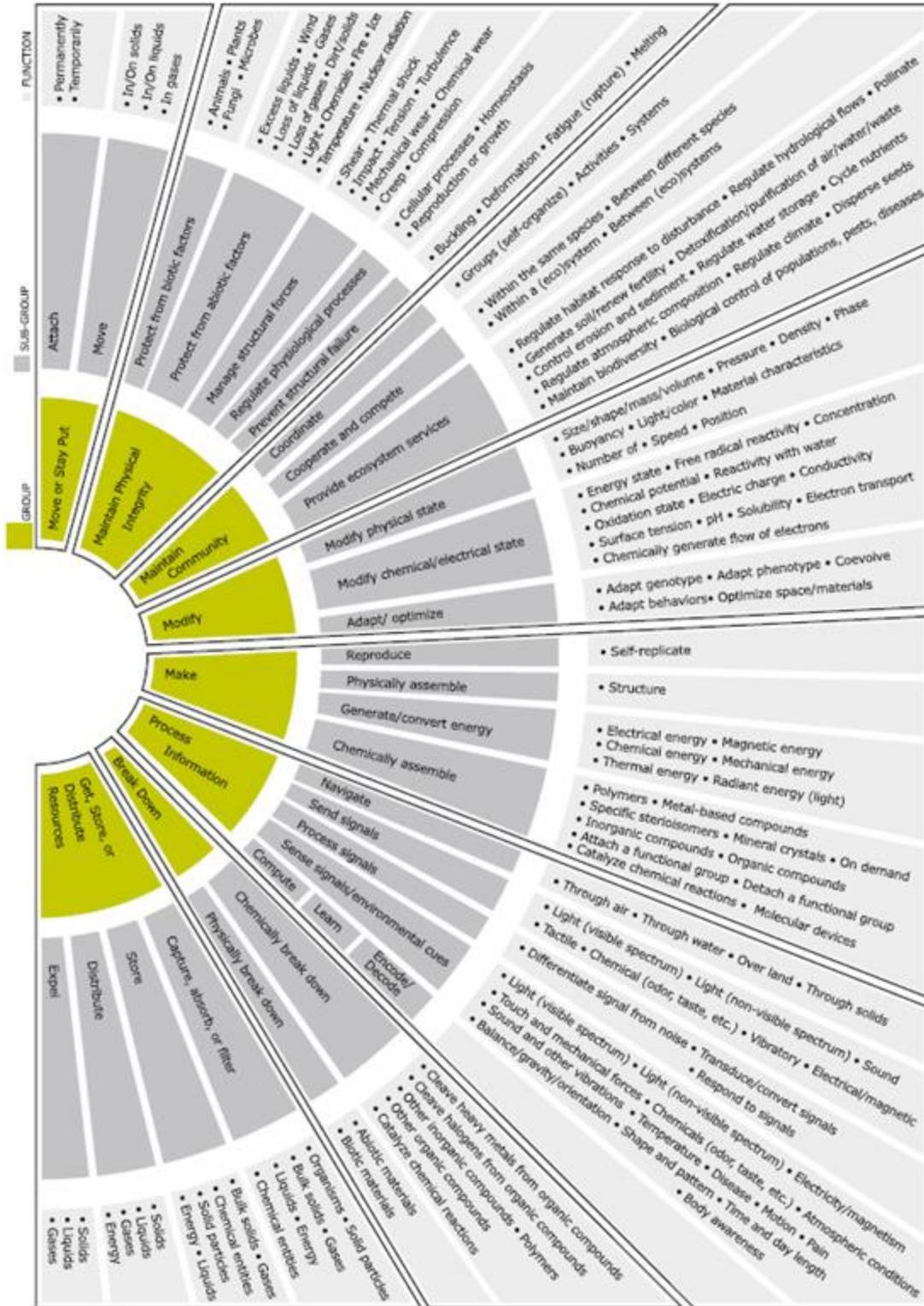


Fig.2.1 Biomimicry Taxonomy



Fig. 2.2 Screenshot of an AskNature product showing the product

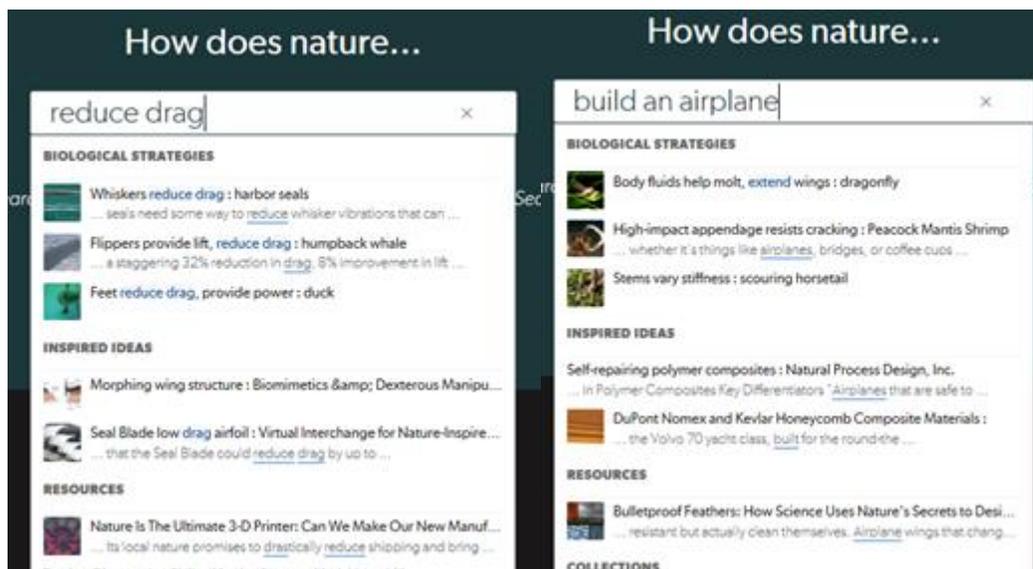


Fig. 2.2 Screenshot of searching on AskNature

The collection of examples in the repository of AskNature is dynamic and enriched through social networking and sharing of biological knowledge.

2.2 Other methods and tools

IDEA-INSPIRE is a computational tool developed by Chakrabarti et al. (2005), which allows a systematic search that enables analogical reasoning using inspirations from natural as well as artificial systems. [6] The approach is function-driven: the tool requires that the design problem be expressed as a triplet, verb–noun–adjective/adverb (VNA), to find natural or artificial systems that fulfil the same function. It may be necessary to divide the problem into sub-problems to focus the solution finding process.

Nagel et al. stated that to abstract problems in engineering design it is common to use functions (actions) instead of specific forms (components), where this approach enabled connections to biological systems which can be described in a similar way by means of their functionalities.[7] Their approach uses an engineering-to-biology thesaurus, which is a tool that facilitates the association of terms from the biological domain to the design problem domain.[8]

3 Non-BioX analogies

3.1 Synectics

The method was proposed by George M. Pence and William J.J. Gordon in 1950s. [9] The idea is approaching creativity and solving the problem with a rational way. Gordon believes that a creativity can be described and taught, the same “psychic” processes drive both invention processes in arts and sciences, and they are analogous, and Individual and group creativity are analogous. With these basic thoughts, he thinks the creativity of people can be trained by showing them how creativity works. The founders of the theory built up a model of what to do with the insights that shows in Figure 3.1. This model explains the mechanism between climate, thinking, and action. When the stimulus is rich enough, the thinking and action can associate and then expand to the climate. With this intersection of the three elements, the innovative work could be generated.



Fig.3.1 A demonstration of Synectics [9]

The researchers believe that this method can break the barriers that exist in the mind of people. The figure below shows a tool called the Spectrum of Thinking that can help people break through their belief system and discover enormous opportunity. The developer believes that a team need enough stimulation to get out to the “challenge your beliefs” spectrum. [10] By obeying the law of the chart, people can generate bold ideas. Though not every bold idea is a great one, there is a big chance that a great idea is a bold one. People need to challenge their thought consequently to discover more revolutionary concepts.

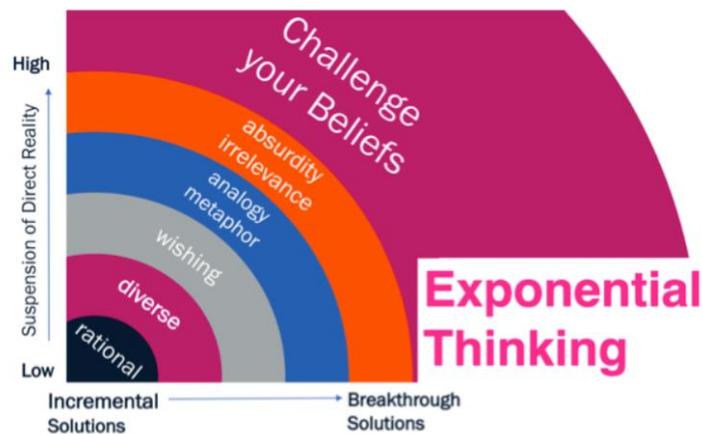


Fig.3.2 Spectrum of Thinking [10]

3.2 WordTree

WordTree diagrams are typically a group of words that are written by team members during the idea generation session. The diagram not only shows the words themselves but also the connections between them. Fig 3.3 shows the basic structure of the WordTree DbA method.

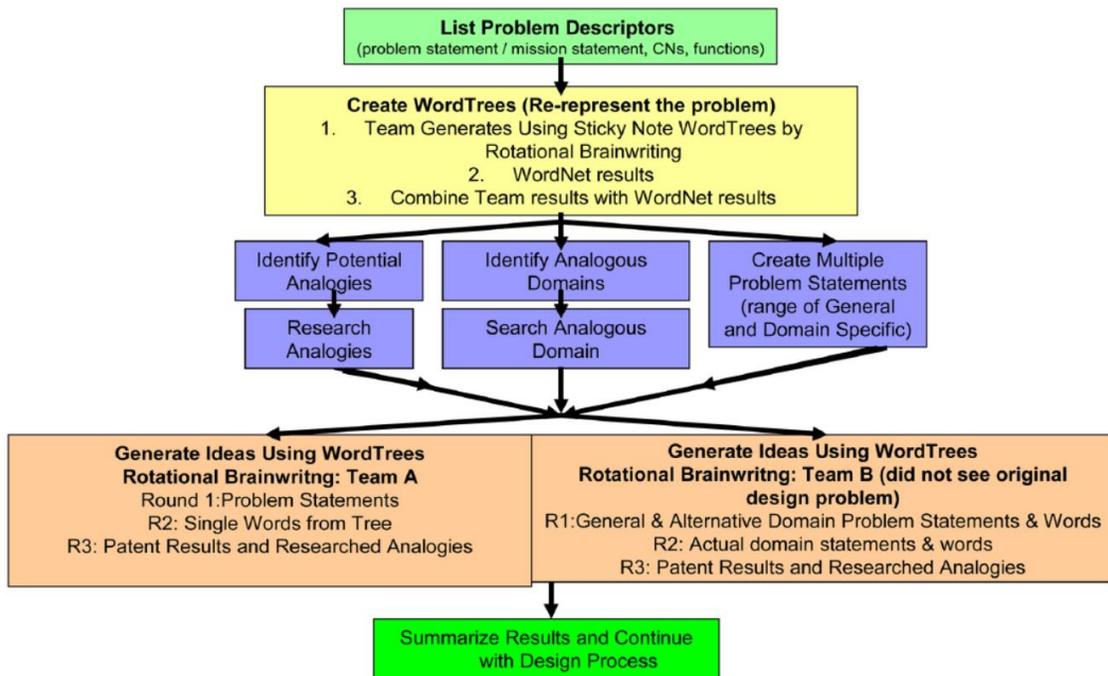


Fig 3.3 Detailed view of the WordTree design-by-analogy method

There is an example of WordTree diagram (Fig.3.4) By drawing the WordTree, for this specific example, it begins with identifying the problem that hidden in its key functions and customer needs. For the next step, the second layer bread down the first layer to several domain. Furthermore, the next layer offers specific possibilities for the problem. And then chose the essential or valuable parts to develop in depth. Finally, for the last layer, there are solutions for the problem that were presented in the beginning. This process helps people develop ideas systematically, which is important for generating rational solutions that link to original solution. Comparing the method of brainstorming that are well known by people, WordTree has the mechanism of building up ideas at the foundation of former ideas. The main advantage of this system is that the method offers a clue for the generation of new thoughts by analogizing the elements with layer. With this clue and clear structure, people can easily recall the connections between the elements and be inspired by the old ideas. And it also helps new team members to catch up the schedule when they join in the project.

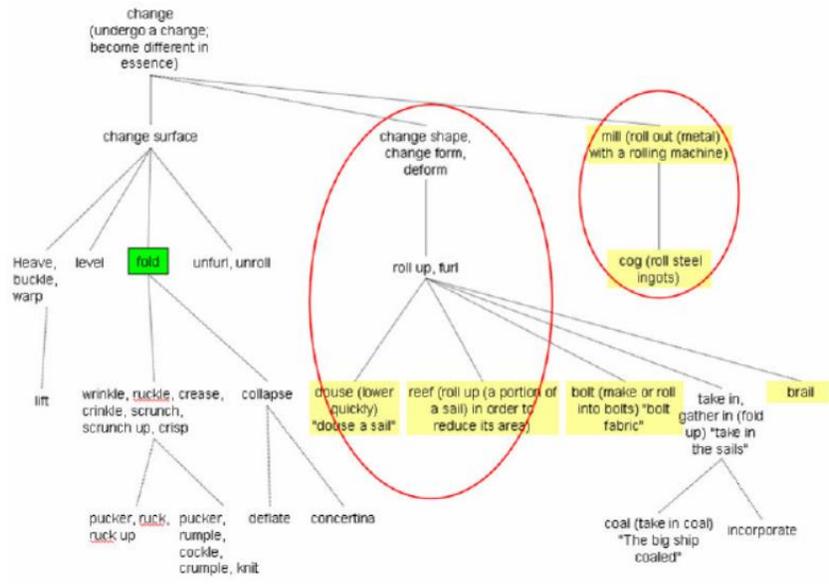


Fig.3.4 An example of WordTree [10]

The WordTree method is a valuable tool for idea generation. It leverages the knowledge of a design team and stimulates the members to dig the existing databases to present unexpected, effectual, analogies and analogous domains. This shows the importance of the method of exploiting new solutions within the old mines of knowledge (databases and team members' knowledge). With utilizing this method, a team can work more effective and systematical.

4 Summary

In this report, we introduced specific methods of Design by Analogy with two main categories. The first one is BioX analogies which include Biomimicry and AskNature. In this section, the definition of and application the methods are presented. They are good ways to gain inspiration from the nature which is sufficient with surprising components. The second one is Non-BioX analogies which focus on more about the rational thinking process. The similarity of the two categories are discovering new opportunity by associating and combining different objects and building. During the process, people would generate new ideas from existing but not utilized components that either exist in nature or human past activities. All the methods that mentioned in this report are helpful for developing creative concepts during designing.

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