Abstraction of Biological Analogies for Design

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Abstract
Biomimetic design uses biological analogies to inspire design concepts. This paper describes a study on selecting and using relevant biological phenomena for design. A hierarchy of forms, behaviors and principles classifies how biological phenomena are presented as potential analogies. The type of similarity achieved between biological phenomena and resulting concepts is affected by the types of information presented in the descriptions of the phenomena. Results suggest that concepts based on strategically similar analogies occur more frequently in the presence of principles that explain the biological phenomena, rather than descriptions of phenomena that focus on forms and behaviors.

Keywords:
Conceptual design, information, biomimetic design

1 INTRODUCTION

Creativity and innovation are fundamental to the engineering design process. Although it is widely believed that creativity cannot be invoked on demand, presentation of appropriate stimuli greatly enhances the generation of concepts. Specifically, the presentation of analogies is one useful approach to enhancing creativity.

Biomimetic design examines biological analogies to solve engineering problems. Although biological phenomena have been used in the past to evoke design solutions, they have not been systematically evoked from a design need. To make biomimetic design more accessible to engineers, a generalized method is required to identify and use relevant biological phenomena for any given engineering problem in an objective and repeatable manner.

This paper describes efforts to determine factors that affect extraction of relevant analogies to apply to an engineering problem. The results of a study involving idea generation using biological phenomena are presented. The relationship between the description of biological phenomena and the type of similarities achieved between concepts and these phenomena will be described.

2 BACKGROUND ON BIOMIMETIC DESIGN

2.1 Related work

Numerous examples of biomimetic design have been documented and include those described in CIRP Annals. Ueda *et al*., have developed the concept of Biological Manufacturing Systems (BMS) to deal with complexity in manufacturing based on biologically inspired ideas such as self-organization, learning and evolution [1-5]. Evolution-based and self-organization models of manufacturing systems were used more recently to design line-less production systems [4] and generate facility layout plans [5].

Alting *et al*. [6] and De Chiffre *et al.* [7] recognize the potential for biomimetics in micro and nano engineering.

Specific to generalizing the process of biomimetic design, Vincent and Mann [8] explore the extension of the TRIZ (theory of inventive problem solving) database to include biological information and principles. TRIZ is a creative problem-solving methodology, using inventive principles to overcome typical system conflicts that were identified by studying over a million patents.

2.2 Previous work

This study uses a biomimetic search tool previously developed that identifies relevant phenomena by locating in natural-language biological knowledge, occurrences of keywords describing engineering problems. While difficulties common to natural-language processing can occur, this approach does not require the tremendous task of categorizing all biological phenomena by engineering function. As such, this approach can readily take advantage of biological knowledge already available in natural-language format. The initial source of biological information is the text *Life, the Science of Biology*, by Purves *et al.* [9]. Previous application problems using this tool include those in design for remanufacture and microassembly [10-12].

3 PROBLEM DESCRIPTION

3.1 Background and purpose

Analogical reasoning maps information from a source domain to a target domain [13], where a similarity forms a relationship between the domains. For biomimetic design, the source domain is biology and the target domain, engineering. It is important to differentiate between analogical matching, which simply relates existing and known analogous phenomena between two domains, and analogical carryover [14], required for the development of novel concepts in engineering based on biological phenomena, which is the goal of biomimetic design.