

Supporting Creative Concept Generation by Engineering Students with Biomimetic Design

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Abstract

Biomimetic design uses ideas from biology as inspiration for design, and is widely recognized as a promising approach to innovation. However, the biomimetic design process can stand to be made more accessible and systematic for engineers. In particular, we identified a number of obstacles that occur when novice designers attempt to retrieve and apply biological analogies to solve design problems. Two main obstacles are: 1) extracting analogical strategies from biology and 2) applying analogical strategies to develop solutions. This paper summarizes our efforts in addressing these two obstacles through a pilot study and subsequent experiments involving engineering students. We found that to facilitate effective analogical transfer in biomimetic design, students require support to recognize relevant causal relations in biology and to explore multiple solutions when generating analogical designs.

1 Introduction

Biomimetic design borrows ideas from nature to solve engineering problems. There are numerous successful applications where creative and innovative solutions were achieved through biomimetic design, from the invention of Velcro to the development of space robotics [1].

Biomimetic design is recognized for its potential to enhance creativity and innovation. Using biological analogies is a subset of design by analogy, which has been shown to inspire creative ideas [2]. In addition, biomimetic design involves inter-domain analogies, as ideas from biology are applied to the conceptually different domain of engineering. Such inter-domain analogies have been found to provoke more novel ideas than intra-domain analogies [3][4].

However, there are challenges in executing effective biomimetic design. Because of the enormous amount of biological knowledge, locating relevant biological analogies can be challenging. One approach is to develop keywords to retrieve relevant information from biological knowledge in natural-language format, much of which is already available. The authors' past work involved identifying biologically meaningful keywords that are more useful for searching biological text than their corresponding engineering keywords [5][6].

Another challenge arises in the recognition and transfer of relevant analogies from biology to engineering. Inter-domain analogies require designers to identify and match relational patterns between source and target domains without obvious superficial similarities [3][7]. While there are many well-known examples of biomimetic design that were first inspired from superficial similarities [8][9], fewer designs were inspired purely from deeper, structural similarities [10].

The challenge of using inter-domain analogies is even more prevalent in novice designers, e.g., engineering students, who often lack the ability to recognize and apply abstract principles from distantly related domains [7]. In our experience, many engineering students have difficulty identifying and applying possible analogies from biology, but instead fixate on irrelevant features in the descriptions of biological phenomena [11].

In this paper, we discuss our efforts to facilitate biomimetic design for novice designers. We explain how a specific semantic relation in biology may play a key role in a designer's recognition of analogical strategies and development of appropriate solutions. We then discuss how the analogical transfer tools we developed affected engineering students in generating creative concepts. We conclude with future research possibilities.