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A natural-language approach to biomimetic design

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Abstract

This paper summarizes various aspects of identifying and applying biological analogies in engineering design using a natural-language approach. To avoid the immense as well as potentially biased task of creating a biological database specifically for engineering design, the chosen approach searches biological knowledge in natural-language format, such as books and papers, for instances of keywords describing the engineering problem. Strategies developed to facilitate this search are identified, and how text descriptions of biological phenomena are used in problem solving is summarized. Several application case studies are reported to illustrate the approach. The value of the natural-language approach is demonstrated by its ability to identify relevant biological analogies that are not limited to those entered into a database specifically for engineering design.

Keywords: Analogical Reasoning; Biologically Inspired Design; Biomimetic Design; Design By Analogy; Natural-Language Approach

1. INTRODUCTION

Many elegant solutions to engineering problems have been inspired by biological phenomena. Although most work in biomimetic design involves specific cases of design that copy particular biological models, not always described is how these biological models were identified or selected. Therefore, it is possible that an engineer open to using biological models for design may not know how to find relevant biological analogies for a given design. The purpose of ongoing work led by the author at the University of Toronto is to develop a generalized methodology by which analogous biological phenomena can be identified and applied to any engineering design problem in an objective and repeatable manner.

Benyus (1997) popularized the notion that humans emulate biological phenomena to design sustainable products and processes. Vincent and Mann (2002) and Vincent et al. (2006) adapted TRIZ, a Russian system of problem solving, to support the transfer of knowledge from the biological to the engineering domain. Chakrabarti et al. (2005) approached the same problem by developing a model to represent causality of natural and artificial systems, and using it to structure information in a database of systems from both natural and artificial domains. Wilson and Rosen (2007) and Wilson et al. (2009) proposed the use of reverse engineering and an ontology to structure a database.

In contrast to building a database of biological phenomena categorized for engineering use, the approach described here takes advantage of the abundant biological information already available in natural-language format (e.g., texts, papers) by searching them directly for relevant phenomena. This approach also avoids the subjective and enormous task of cataloging all of biological phenomena for engineering.

This paper will summarize 10 years of work at the University of Toronto on the natural-language approach to biomimetic design. First highlighted are challenges in natural-language processing and analogical reasoning, and work toward overcoming these challenges. Analogies identified using this approach for case studies in design for remanufacture, microassembly, and protection from lunar dust are then described to illustrate the process, as well as highlight further insights and challenges.

2. METHODS

2.1. Search for biological analogies

This approach has been implemented in the form of a computerized search tool that locates in biological knowledge in natural-language format, such as texts and papers, instances of keywords describing the engineering design problem.

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