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Biomimetic design through natural language analysis to facilitate cross-domain information retrieval

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Abstract

Biomimetic, or biologically inspired, design uses analogous biological phenomena to develop solutions for engineering problems. Several instances of biomimetic design result from personal observations of biological phenomena. However, many engineers' knowledge of biology may be limited, thus reducing the potential of biologically inspired solutions. Our approach to biomimetic design takes advantage of the large amount of biological knowledge already available in books, journals, and so forth, by performing keyword searches on these existing natural-language sources. Because of the ambiguity and imprecision of natural language, challenges inherent to natural language processing were encountered. One challenge of retrieving relevant cross-domain information involves differences in domain vocabularies, or lexicons. A keyword meaningful to biologists may not occur to engineers. For an example problem that involved cleaning, that is, removing dirt, a biochemist suggested the keyword "defend." Defend is not an obvious keyword to most engineers for this problem, nor are the words defend and "clean/remove" directly related within lexical references. However, previous work showed that biological phenomena retrieved by the keyword defend provided useful stimuli and produced successful concepts for the clean/remove problem. In this paper, we describe a method to systematically bridge the disparate biology and engineering domains using natural language analysis. For the clean/remove example, we were able to algorithmically generate several biologically meaningful keywords, including defend, that are not obviously related to the engineering problem. We developed a method to organize and rank the set of biologically meaningful keywords identified, and confirmed that we could achieve similar results for two other examples in encapsulation and microassembly. Although we specifically address cross-domain information retrieval from biology, the bridging process presented in this paper is not limited to biology, and can be used for any other domain given the availability of appropriate domain-specific knowledge sources and references.

Keywords: Biomimetic, Biologically Inspired, Bioanalogous Design; Concept Generation; Domain Lexicons; Information Retrieval

1. INTRODUCTION

Biomimetic design uses biological phenomena as inspiration for solutions to engineering problems. One well-known example of biomimetic design is the development of Velcro after observing that cockleburs attach to clothing and fur.

In the development of synectics, Gordon (1961) observed that biology provided the richest source of direct analogies. Benami and Jin (2002) note that analogies from conceptually different domains result in more creative, original ideas. The success of many biologically inspired designs supports that biology is a good source of analogies. However, designers who want to use biological analogies are generally limited by their knowledge of biology. We believe that a systematic search of biological phenomena relevant to a specific design problem will identify a greater variety of potential analogies and likely result in more creative design than simply using analogies that come to mind. We have chosen to take advantage of the enormous amount of biological information already available in natural-language format, such as books, journals, etc. Thus, we developed a method that uses natural language processing to extract relevant biological phenomena from these existing sources of biological knowledge.

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