A Computational Concept Generation Technique for Biologically-Inspired, Engineering Design

J.K.S. Nagel and R.B. Stone
Oregon State University, USA

The natural world provides numerous cases for analogy and inspiration in engineering design. During the early stages of design, particularly during concept generation when several variants are created, nature can be used to inspire innovative solutions to a design problem. However, identifying and presenting the valuable knowledge from the biological domain to an engineering designer during concept generation is currently a somewhat disorganized process or requires extensive knowledge of a particular method. The proposed research aims to define and formalize the information identification and knowledge transfer processes, which will enable systematic development of biologically-inspired, engineering designs. The computational framework for discovering biological inspiration during function-based design activities is presented and discussed through an illustrative example.

Introduction

Engineering design is considered both an art and a science, which encourages the use of engineering principles, imagination and a designer’s intuition to create novel engineering solutions. Nature is a powerful resource for engineering designers. The natural world provides numerous cases for analogy and inspiration in engineering design [1-4]. Biological organisms, phenomena and strategies, herein referred to as biological systems, are, in essence, living engineered systems. These living systems provide insight into sustainable and adaptable design and offer engineers billions of years of valuable experience, which can be used to inspire engineering innovation. Many engineering breakthroughs have occurred based on biological phenomena and it is evident that mimicking biological
systems or using them for inspiration has led to successful innovations (e.g., velcro, flapping wing micro air vehicles, synthetic muscles, self-cleaning glass, etc.).

Nature has influenced engineering and the engineering design process. While inspiration from nature can be taken at multiple stages in the engineering design process, it most notably occurs during concept generation. When inspiration in the form of analogies, metaphors and connections from multiple engineering domains and other sources (e.g., biological domain) are utilized for developing novel or creative solutions to a design problem. Concept generation methods and tools help stimulate designer creativity and encourage exploration of the solution space beyond an individual designer’s knowledge and experience [5-13]. There are multiple approaches to concept generation for engineering design; however, most are not computational. Although in recent years, computation-based or automatic concept generation has gained importance in the engineering design research community and has taken many forms [14-20]. Identifying and presenting the valuable knowledge from the biological domain to an engineering designer during concept generation is currently a manual, in most cases, and somewhat disorganized, process. The proposed research aims to define and formalize the information identification and knowledge transfer processes, which will result in a systematic method for developing biologically-inspired, or biomimetic, designs.

This paper proposes and explores the third version of the established automatic concept generation software developed by researchers of the Design Engineering Lab. In order to facilitate concept generation for biologically-inspired, engineering design, two bodies of knowledge are required-successful engineered systems and biological systems-both indexed by engineering function. A Design Repository [21] containing descriptive product information serves as the engineered systems body of knowledge. Instead of creating a database containing functionally decomposed biological systems, similar to the design repository, an introductory biology textbook serves as the biological systems body of knowledge. To circumvent the terminology difference issue-indexed by natural language rather than engineering function—an engineering-to-biology thesaurus is utilized [22]. Structurally, the thesaurus acts as a set of correspondent terms to the functions and flows of the Functional Basis [23], which provides term mapping between the biological and engineering domains for the support of concept generation. Integrating biological system information with an established, computational method for concept generation enables designers to consider taking inspiration from biology without having to expend extra effort to learn a new method.