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Biologically inspired design

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ABSTRACT

This paper reviews research on biologically inspired design, and has three main parts. The first part surveys examples relevant to three groupings of manufacturing research. The second part presents general methods that support biomimetic design, including different approaches for the steps involved in identifying and applying relevant biological analogies for any given problem. The third part details examples that illustrate the use of a general biomimetic design method, which identifies analogies from natural-language biological information. Finally, insights and conclusions are drawn and synthesized.

1. Introduction

Many elegant solutions to engineering problems have been inspired by biological phenomena. Examples of biologically inspired design relevant to three groupings of manufacturing research are presented in Section 2. While much work in biologically inspired design involves specific cases of design that copy particular biological models, not always described is how these biological models were identified or selected. It is possible that engineers open to using biological models for design may have difficulty in finding relevant biological analogies for a given problem. Therefore, Sections 3 and 4 present an overview of generalized methodologies that support biologically inspired design. Section 5 details examples that demonstrate the use of a generalized methodology to identify and apply biological analogies to engineering problems. Section 6 concludes with insights following the examples from both Sections 2 and 5.

1.1. Terminology

As many fields of study involve the intersection between biology and engineering, it is useful to define related, commonly used terms. This will clarify the position of biologically inspired design in this intersection. In addition, several terms are used interchangeably for biomimetic or biologically inspired design.

Bioengineering, biological engineering, biotechnical engineering: Application of engineering principles and tools, e.g., physics, mathematics, analysis and synthesis, to solve problems in life sciences, and may involve the integration of biological and engineering systems.

Biomechanics: Application of mechanical principles, e.g., mechanics, to study and model the structure and function of biological systems.

Biomedical engineering: Application of engineering principles and techniques to the medical field, e.g., design and manufacture of medical devices, artificial organs, limbs, etc.

Biophysics: Term used by Otto Schmitt to mean both: applying physical sciences to solve problems in biological sciences, and biologists' approach to problems in physical sciences/engineering [36,81].

Bionics: Application of biological function and mechanics to machine design. Jack E. Steele used the term ~1960 to mean 'like (ic) life (bio)' or systems that copy some function or characteristic from natural systems [110]. However, the 1970s television series, Bionic Woman, about a human with electromechanical implants, also gives 'bionic' the connotation of 'biological + electronics,' or use of electronic devices to replace damaged limbs and organs.

Biomimetics: Used in title of paper by Schmitt, and defined as, the 'study of formation, structure, or function of biologically produced substances and materials (as enzymes or silk) and biological mechanisms and processes (as protein synthesis or photosynthesis) especially for the purpose of synthesizing similar products by artificial mechanisms which mimic natural ones' [36,81,110].

Biomimesis, Biomimicry, Biognosis, Bioinspiration, Biomimetic design, Bioanalogous design, Biologically inspired design: Synonymous with biomimetics to mean emulating natural models, systems, and processes to solve human problems. The term 'biomimcry' is in the title of a popular book by Janine Benyus, that gives it a connotation of sustainability [3].

With the exception of the bidirectional term biophysics, there are two main directions in the above intersection between biology and engineering. The first aims to apply principles in engineering to solve problems in life sciences, and includes terms such as bioengineering, biomedical engineering and biomechanics. The second aims to apply principles of biological systems to solve problems in engineering. This paper will focus on the latter, using the terms biomimetic design and biologically inspired design interchangeably.

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