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EXPLORING THE USE OF FUNCTIONAL MODELS AS A FOUNDATION FOR BIOMIMETIC CONCEPTUAL DESIGN

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ABSTRACT

The natural world provides numerous cases for analogy and inspiration. From simple cases such as hook and latch attachments to articulated-wing flying vehicles, nature provides many sources for ideas. Though biological systems provide a wealth of elegant and ingenious approaches to problem solving, there are challenges that prevent designers from leveraging the full insight of the biological world into the designed world. This paper describes how those challenges can be overcome through functional analogy.

Through the creation of a function-based repository, designers can find biomimetic solutions by searching the function for which a solution is needed. A biomimetic function-based repository enables learning, practicing and researching designers to fully leverage the elegance and insight of the natural world. In this paper, we present the initial efforts of functional modeling natural systems and then transferring the principles of the natural system to an engineered system.

Four case studies are presented in this paper. These case studies include a biological solution to a problem found in nature and engineered solutions corresponding to the high level functionality of the biological solution, i.e., a fly's winged flight and a flapping wing aircraft. The case studies show that unique, creative engineered solutions can be generated through functional analogy with nature.

1 INTRODUCTION

The natural world contains some of the most elegant, innovative and robust solution principles and strategies. Biomimetic design aims to fully leverage the insight of the natural world into the engineered world. Because of numerous challenges, biomimetic design is still undeveloped as a method for formal concept generation. Allowing design engineers formal and full access to the solution principles and strategies of the natural world remains beyond current methods and knowledge.

At times, engineered technologies are unable to implement the physical principles used in the biological system. Articulated-wing flying vehicles are one example. Prior to the initial flight by the Wright brothers with fixed-wing flight, articulated-wing flight was attempted but failed. At the time, fixed-wing flight proved more feasible. However, articulated-wing flight is now possible, allowing for micro and nano air vehicles that fly at Reynolds numbers infeasible with fixed-wing flight.

Another, and more fundamental challenge, is that the effort and time required to become a competent engineering designer creates significant obstacles to becoming sufficiently knowledgeable about biological systems to effectively execute biomimetic design (and of course, the converse could be said).

Functionally based concept generation methods provide a unique opportunity to extend biomimetic design and integrate it fully into engineering design practice. In the last three decades, concept generation has made significant advances from art to science, from the informal to the formal. Methods are continuously being developed, tested and implemented in industry and taught to our engineering community [1]. Inherent to this formalization of conceptual design is the recognition that devices are designed to solve specific functions. Thus, even if not explicitly performed, specifying and modeling the desired function of a product or system is fundamental in the conceptual design process.

Additionally, representing products by function has enabled the creation of design repositories that allow designers to access solution principles that are outside their personal knowledge or expertise [2-5]. The ability of functional representation to allow designers to access such design information is a key strength of extending biomimetic design through the method of functional modeling. If extending biomimetic design to the full range of designers, design researchers and design students requires extensive knowledge in biology, the insight of the natural world will never be fully accessible to engineering design.

The objectives of the research presented in this paper are to create the methods and discover the knowledge needed to enable a function-based biomimetic design repository. First, a brief summary of previous work in biomimetic design will be provided. Next, the research methodology that was followed to generate the case studies found in the fourth section of this paper will be discussed. Finally, conclusions reached thus far in this research will be discussed as well as a summary of future work that remains to be completed.