Biologically inspired design: process and products

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Biologically inspired engineering design uses analogies to biological systems to develop solutions for engineering problems. We conducted a study of biologically inspired design in the context of an interdisciplinary introductory course on biologically inspired engineering design in Fall of 2006. The goals of this study were to understand the process of biologically inspired engineering design and to provide insight into biologically inspired design as a type of design activity. This paper provides a descriptive account of biologically inspired design processes and products, and summarizes our main observations: 1) designers use two distinct starting points for biologically inspired design; 2) regular patterns of practice emerge in biologically inspired design; and 3) certain errors occur regularly in the design process.

Keywords: engineering design, biologically inspired design, design cognition, design process, design techniques

Biologically inspired design uses analogies to biological systems to develop solutions for engineering problems. Biologically inspired design is gaining importance as a wide-spread movement in design for environmentally conscious sustainable development (e.g. Papanek, 1984; Wann, 1990; Benyus, 1997; Anastas and Warner, 2000) that often results in innovation (French, 1998; Vogel, 2000; Collins and Brebbia, 2004; Forbes, 2005). Bosner (2006) and Bosner and Vincent (2006) trace the growth of biologically inspired design patents. From the perspective of design studies, a number of characteristics make biologically inspired design an especially interesting problem to study. (1) Biologically inspired design is inherently interdisciplinary. By definition, it is based on cross-domain analogies requiring expertise across two disparate domains (engineering and biology). (2) Since the objects, relations and processes in biology and engineering are very different, biologists and engineers typically speak a very different language, creating communication challenges. (3) Since biologists in general seek to understand designs occurring in nature while design engineers generally seek to generate designs for new problems, they typically use different methods of investigation

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and often have different perspectives on design. (4) Biological designs typically result in more multi-functional and interdependent designs than engineering designs. (5) The resources, such as materials and processes, available in nature to realize an abstract design concept typically are very different from the resources available in the engineering domain.

The literature in the design sciences contains many case studies of biologically inspired design. Vincent and Man (2002), for example, describe their imitation of the design of pinecones to design clothing that can help regulate body temperature. Other examples include design of micro-robots that can walk on water mimicking the locomotion of the basilisk lizard (Floyd et al., 2006), and design of nano-scale super-hydrophobic coatings inspired by the self-cleaning mechanism of lotus leafs (Zhu et al., 2005), and dynamic server allocation for internet housing inspired by forager allocation in honey bee colonies (Nakrani and Tovey, 2004). Beer et al. (1999) and Bar-Cohen and Brazeal (2003) review several cases of biomimetic robot designs.

Recently, there also have been some attempts to build databases for supporting biologically inspired design. The Biomimicry Institute (http://www.biomimicry.net/), for example, provides the AskNature (www.asknature.org/) online library of research articles on biomimetic design indexed by function. Chakrabarti et al.'s (2005) SAPPHIRE tool provides English language descriptions of the structures, behaviors and functions of biological and engineering designs previously used in biomimetic design.[1] It also uses verbs to describe engineering design problems, and retrieves biological and engineering designs based on matches between the verbs used in the problem descriptions. Based on experiments with the SAPPHIRE tool, Sarkar and Chakrabarti (2008) discovered that diagrammatic representations of biological systems lead to generation of more and better design ideas than textual representations. Mak and Shu (2004) provide a taxonomy of verbs that relate biological and engineering designs. They (Mak and Shu, 2008) have found that functional descriptions of biological systems in the form of flow of substances among components improve the quantity and quality of the generated design ideas. Nagel et al. (2008) describe a small database of models of biological systems based on function flow. Linsey et al. (2008) found that functional annotations on diagrams increase the chances of successful biological analogies.

However, at present there is little understanding of the *processes* of biologically inspired design as a design activity. Vincent et al. (2006) provide one of the few information-processing models of the *how* of biologically inspired design instead of the *what*. However, their model, based on the TRIZ model of creative design (Altshuller, 1984) is *normative*. The current paper provides a descriptive account of the biologically inspired design process through an in situ study conducted on the practices and products of designers in the context of