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USE OF BIOLOGICAL PHENOMENA IN DESIGN BY ANALOGY

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ABSTRACT

Biomimetic design involves the use of biological phenomena as analogies to solve engineering problems. The use of biological knowledge in natural-language format to support biomimetic design removes the need to create and maintain a database of biological phenomena for engineering purposes. However, challenges arise in recognition and extraction of relevant strategies in biological phenomena and the application of these strategies to the target problem.

This paper describes two studies of how descriptions of biological phenomena are used to develop solutions to an example problem. Participants were informed of the types of similarities to avoid that were observed in a previous study. The occurrence of such non-analogous similarities declined.

Two types of fixation were observed during the first study: fixation on certain words instead of the overall strategy presented in descriptions and fixation on certain solutions regardless of the description used as stimuli. The second study aimed to reduce these types of fixation. While fixation was observed to decrease in the second study, the need for support of analogical mapping persisted.

1. INTRODUCTION

Biomimetic design uses biological phenomena as analogies to help solve design problems. First presented will be terminology and related work in analogical reasoning, followed by existing work in design by analogy. Next described is how biomimetic design fits into the technique of Synectics and how TRIZ is relevant to biomimetic design.

1.1. Analogical Reasoning

Analogical reasoning involves the transfer of information from a source to a target domain. The source domain contains the analogous phenomenon, and the target domain contains the problem to be solved by analogy (Vosniadou & Ortony 1989).

Similarity links analogically related items between the source and target domains. Surface similarity is grounded in easily retrievable aspects of representations, and is based on shared object attributes, e.g., color of two tiles. Deep similarity is based on relational structures between two domains, e.g., flow of heat vs. flow of water (Gentner 1989).

The analogies abstracted from similarity relationships can be further divided into two types. Within-domain analogies are used between the same or at least conceptually close, source and target domains, e.g., from one type of electromechanical product to another. Between-domain analogies are used between different source and target domains, e.g., from biological phenomena to electro-mechanical products.

Benami and Jin (2002) developed a Cognitive Model of Creative Conceptual Design that captures the relationship between the properties that stimulate cognitive processes and the design operations that facilitate cognitive processes. The underlying conclusion of the study was that ambiguous entities stimulated more ideas than non-ambiguous entities, which tend to be fixating. Alternatively, between-domain analogies resulted in more creative, original ideas than within-domain analogies, which resulted in a greater quantity of ideas.

1.2. Related Work in Design by Analogy

A number of design frameworks exist for facilitating the abstraction of within-domain analogies. Of these, there are knowledge based systems that rely on surface similarity, such as Syn, where topological patterns of air circulation systems are matched with the requirements of the given architectural design problem (Goel 1997). More complex is the Ideal system developed by Bhatta and Goel (1994) that evaluates functional and causal patterns with no topological information such that deep functional similarities are explored.

McAdams and Wood (2000) developed a quantitative metric for design-by-analogy, which is based on the deep functional similarity of products within the domain of