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EFFECTIVE ANALOGICAL TRANSFER USING BIOLOGICAL DESCRIPTIONS RETRIEVED WITH FUNCTIONAL AND BIOLOGICALLY MEANINGFUL KEYWORDS

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ABSTRACT

While biology is well recognized as a good source of analogies for engineering design, the steps of 1) retrieving relevant analogies and 2) applying these analogies are not trivial. Our recent work translated the functional terms of the Functional Basis into biologically meaningful keywords that can help engineers search for and retrieve relevant biological phenomena for design, addressing step 1 above. This paper reports progress towards step 2: identifying and overcoming obstacles to effective analogical transfer and application of biological descriptions retrieved with functional and biologically meaningful keywords.

This work revealed that the presence of, and ease of recognizing, causal relations (relationships between two actions where one causes another) in biological descriptions plays a key role in the quality of analogical transfers. We observed that novice designers found it difficult to correctly transfer analogies when they could not easily recognize the causal relations present in biological descriptions. Two major factors that rendered this recognition difficult were: 1) a large number of action words appearing in the descriptions, and 2) key action words being used in the passive voice. To overcome these factors, we propose a template that guides designers to 1) recognize the relevant causal relations in biological descriptions and 2) focus on the functional elements of the causal relations.

1. INTRODUCTION

Many researchers in both cognitive science and design engineering have recognized analogy as a significant tool in making creative leaps during problem solving and design (Gentner 1989, Goel 1997, Holyoak and Thagard 1996). Our past and current research focuses on design using biological analogies, i.e., biomimetics. Gordon (1961) recognized biology as a promising source of analogies and humans have mimicked biological entities throughout history to serve their needs. While many successful applications have already been achieved, there lies an almost infinite amount of potential analogies in biology yet to be explored, as biological knowledge sources are quickly expanding (Rebholz-Schuhmann et al. 2005).

In general, the use of analogy involves two steps. First, the source analogy is retrieved and selected, and second, the source analogy is mapped to the target, or problem of interest, whereby inferences are generated about the target (Holyoak and Thagard 1996). At the Biomimetics for Innovation and Design Laboratory at the University of Toronto (BIDLab), we have studied in detail both the retrieval and mapping processes involved in biomimetic design.

Chiu and Shu (2007a) developed a systematic retrieval method for biologically meaningful keywords, which are words that are well suited to search natural-language text for biological information relevant to design problems. This method was then adapted and refined to translate the function sets of the Functional Basis into a set of biologically meaningful keywords (Cheong et al. 2008).

We have also studied challenges in using analogies from biological knowledge in natural-language format, particularly the extraction of strategies used in biological phenomena and applying these strategies to design problems (Mak and Shu 2004a, Mak and Shu 2004b). We will present in more detail our previous work in the Background section.

In the research reported in this paper, we aim to observe the effectiveness of source analogies retrieved and identify challenges in using the given analogies. We approached this by studying how novice designers use biological descriptions that are retrieved with engineering functional keywords versus biologically meaningful keywords to solve design problems.