Student Name: Sonal Keshwani
SR No. : 08736
Research Supervisor: Prof. Amaresh Chakrabarti
CPDM, IISc

Abstract

The aim of this research is to support designers in novel idea generation using design-by-analogy method, in particular, by using analogies from the biological domain. The motivation behind this research is to aid designers in creating more novel products that in turn would positively influence the market share of companies producing those products.

In recent years, biological analogies have been extensively utilized by researchers and designers for product development. Also, previous studies have shown that design methods influence novelty. Therefore, the first empirical study of this research was conducted to understand how biological analogies compare with the other design methods in terms of novel idea generation. This study compared the influence of using biological analogies (in the form of biocards) with brainstorming – a substantially popular design method for novel idea generation. The results showed that using biocards over brainstorming led to an incremental increase in novelty of concepts; however, novelty leaps were not observed. This study pointed to the need for addressing the factors associated to biological analogies, which in turn would support designers to produce novel designs using these analogies. Three such factors, which influence novelty in both biologically inspired design and design-by-analogy methods, were identified and studied in this research. These factors were the following: a) conceptual-distance between the source- and the target-domain of an analogy; b) level of comprehensiveness at which an analogy is explained; and c) retrieval of analogy.

The second empirical study was conducted to understand the influence, on novelty, of the factors (a) and (b) above. In factor (a), the source-domain is the domain from where the analogy is drawn, and the target-domain is the domain to which the analogy is applied. We defined 'distance between the source-and the target-domain' as the conceptual closeness between these two domains, on the basis of which analogies were systematically classified as biological-domain, cross-domain or in-domain analogies. In factor (b), we defined 'level of

comprehensiveness in explanation of an analogy' as the relative depth at which an analogy is explained, on the basis of which explanations of analogies were systematically varied as surface, shallow (both shallow and surface are less comprehensive) or deep (more comprehensive). The major findings from the study were the following: (1) the analogies from biological-domain produced significantly greater novelty in designs over analogies from cross- and in-domain for less comprehensive explanations; the analogies from cross-domain and biological domains had no significant difference in novelty in designs for more comprehensive explanations; (2) levels of comprehensiveness in explanation of an analogy influences novelty. While the finding (1) indicates the need of a support to enable the designers in retrieving analogies from specific analogical domains - as also identified in the factor (c) above, the finding (2) indicates the need of enabling the designers in generating explanations of analogies at the various levels of comprehensiveness.

Therefore, we developed a support with the following two aims: (1) to support designers in retrieving analogies – to address factors (a) and (c); and (2) to support designers in generating explanation of an analogy at the various levels of comprehensiveness - to address the factor (b). In order to support designers in retrieving analogies from various analogical domains, we proposed an approach that automatically structures natural language documents from the Internet into a common causal language – which was chosen here as SAPPhIRE model of causality (Chakrabarti et al. 2005). This approach is implemented using the following steps: (a) retrieval of natural language documents from the Internet; (b) removal of non-SAPPhIRE sentences; (c) decomposition of sentences into clauses; and (d) prediction of SAPPhIRE constructs of each clause. Each of the four steps were evaluated on manually created test data. Using these steps, a structured database of 193 unique systems was created. The number of systems in this database can be further increased automatically. This database will be embodied in Idea Inspire - a computational tool for retrieving analogies. This addressed the factor (c) mentioned previously.

In order to automatically generate explanations, an explanation generation system was created. This system generates explanations at the three levels of comprehensiveness – deep, shallow and surface, that were proposed in the second empirical study. This automatic explanation generation system builds upon the structured database of analogies created previously and uses the templates to generate the explanations. For evaluating the performance of this automated explanation generation system, the automatic and manually generated deep explanations of four documents were compared with each other. The aim of this comparison was to find the percentage overlap between the two explanations. This overlap was found to be 40%. As this explanation generation system is built upon the automatically structured database of analogies, the errors in this automatic structuring of analogies were reflected in performance of explanation generation system, leading to low percentage overlap. As far as we are aware, this is the first attempt in the direction of automatic generation of analogies, therefore, we could not benchmark our results with similar research in literature in the domain of design-by-analogy. This addressed the factor (b) mentioned previously

This support needs to be further developed to filter the retrieved results based on the conceptual-distance between the source and the target domain of an analogy – to address factor (a). The state-of-art approaches need to be implemented, in future, to increase the accuracy of the structuring of the database and the explanation generation system. Further, more comprehensive evaluation needs to be conducted to study the influence of the automatically generated explanations of analogies on the variables like understanding of the analogies among the designers, novelty of the concepts produced using the SAPPhIRE-like explanations of the analogies used.