Title
Generic Modeling in Analogical Reasoning

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The use of analogical reasoning in creative problem solving often involves transfer between distant problems. Some cognitively-inspired computational models of analogical reasoning describe "direct transfer" where the knowledge of a source situation is directly transferred to the target situation, e.g., SME (Falkenhainer et al., 1989) and ACME (Holyoak and Thagard, 1989). But some psychological studies, such as Gick and Holyoak's (1983), indicate that sometimes higher-level abstractions may mediate the transfer between the source and the target. Our work on creative device design has led us to a theory, called *model-based analogy* (MBA), that provides a computational account of learning and use of such higher-level abstractions that we call *generic models*. Generic models in device design capture knowledge of functional and causal patterns abstracted from case-specific device models. Since a generic model may be acquired from one design case and instantiated in the context of adapting an entirely different case for solving a target problem, they mediate (cross-domain) analogical transfer.

The Process of Model-Based Analogy

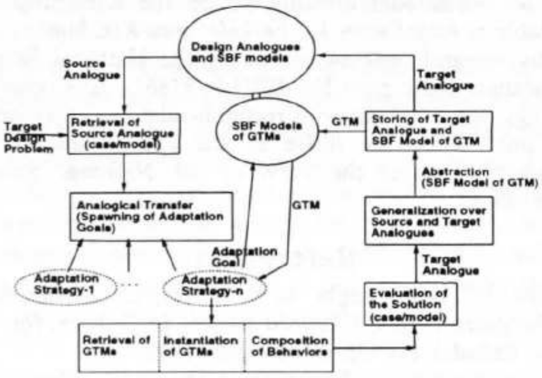

Figure 1: **Part of IDEAL's Process for Analogical Design**

IDEAL is the computer system that implements the MBA theory in the context of device design. IDEAL takes as input a specification of the functional and structural constraints on a desired design (i.e., the target design problem), and gives as output a structure (i.e., the solution) that realizes the specified function and also satisfies the structural constraints. Figure 1 illustrates one part of IDEAL's processing, the part that uses generic models of a specific kind called *generic teleological mechanisms* (GTMs). GTMs specify abstract patterns of relations between output functions and internal behaviors for achieving the functions, for example, feedback. They are "mechanisms" because they specify behaviors (or processes), "teleological" because they are in the service of functions, and "generic" because they pertain to classes of device domains, not just to a specific device or a particular device domain. The case-independent GTMs are abstractions of case-specific *Structure-Behavior-Function* (SBF) models (Goel, 1991) that explain how the structure of a design realizes its function. For details, see (Bhatta, 1995; Bhatta and Goel, 1993).

IDEAL provides a testbed for experimenting with generic modeling in analogical reasoning. We have tested IDEAL in four different domains, namely, the domains of simple electric circuits, heat exchangers, electronic circuits, and mechanical devices (including momentum controllers and velocity controllers) for both learning and use of GTMs. In particular, we tested IDEAL with a dozen design problems from these four different domains that involved learning and use of six different GTMs. IDEAL could not only learn and use the GTMs but it also used the learned GTMs for cross-domain analogical transfer. Our experiments with IDEAL indicate that (1) for analogical device design, useful device abstractions include GTMs that capture patterns of relations between device functions and internal causal behaviors and (2) device abstractions such as GTMs may mediate analogical transfer between different design problems including distant problems in different device domains.

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