Designs for the Future

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The Problem: Computer aided design tools built to date have typically shared three important characteristics: *(i)*, they are intended for use relatively late in the design process, *(ii)* they typically employ a style of interaction familiar to programmers but not necessarily intuitive to designers, and *(iii)* they capture the final product alone, recording almost none of the thinking, exploration, or rationale that motivated the endproduct. We are working to change this by designing and building a set of programs that are focused on the early, conceptual stage of design, that use as their input language that most familiar of interaction media, a design sketch, and that are capable of capturing the design process as well as the final product.

Motivation: We see particular value in creating tools that aid at the earliest design stages and that provide for the capture and subsequent dissemination of design rationale information. Such tools would assist those faced with redesign avoid the traditional task of intellectual archeology, i.e., attempting to determine why the design is as it is, typically tripping over the very same problems encountered and solved, but not recorded, by the orginal designers. While the focus of our current work is physical artifacts, we believe the issues explored here are considerably broader, and are equally relevant to nearly everything we design, including software, policies, organizations, etc.

Previous Work: Our previous work produced a program that begins with a sketch and produces a model that we call a *behavior-ensuring parametric model*, a parametric model augmented with constraints, derived from the sketch itself, which ensure that any solution to the parametric model will in fact produce the desired behavior described for the device (see [4], [5]). Our techniques focus on the geometry of devices which have time varying engagements (i.e., variable kinematic topology), and are thus complementary to the well known design techniques for fixed topology mechanisms, such as the gear train and linkage design techniques in [1]

There had been a large body of work in design rationale capture and construction; [3] offers a good overview of work relevant to ours. Our approach can be seen as similar in spirit to efforts in [2] in that it reasons about causality, but out approach is unique, in its ability to determine which dimensions are relevant, and in its ability to generate a wide variety of design alternatives via reverse engineering.

Approach: We are building a system and environment that is in many ways completely familiar to a working engineer: it will allow the engineer to sketch and verbally describe a design, much as he does in the presence of other designers, with one important difference: the "audience" viewing the sketch and listening to the description will be a computer. The system will act as an assistant in much the same way as human assistants, making notes about the design and its rationale, asking sensible questions about the alternatives chosen and eventually suggesting variations on the design.

The tools we are developing will be able to deal with design sketches as input: We want engineers to be able to communicate with their design tools by sketching out their conceptual designs with the same *imprecision* they are used to, using rough sketches that indicate relationship among dimensions rather than the precise values of the dimensions (see research abstracts by Alvarado and Sezgin, this volume). We also want engineers to be able to describe the behavior of their devices in ways that feel natural, i.e., with voice and gestures (see research abstract by Oltmans, this volume).

We believe that design rationale capture can be facilitated by tools that reverse engineer a design and that offer a family of design alternatives. One way to generate design rationales automatically is to reverse engineer the final design (i.e., explain to yourself why it works); a second, somewhat less automatic though still quite revealing approach is to show the designer a set of alternative designs and ask why those were not selected.

Difficulty: Engineers have an apparently well-developed ability to envision the behavior of a device from even a crude sketch and a minimal description of the desired behavior. Capturing that kind of informal, qualitative, mechanistic reasoning presents an array of imposing problems: interpreting sketches, understanding mechanisms, qualitative reasoning about behavior, and encoding and using knowledge about design.

Impact: Tools of the sort we are developing will enable exploration of significantly more design alternatives. Consider, for example, the variant designs for a circuit breaker shown below. The first is the most conventional design; the other two alternatives were produced automatically by our program, are completely functional, and exhibit possibilities that might have been overlooked by the designer. A second impact of our work will be to make rationale capture *less* trouble than it is worth. This has the ability to change the practice of re-design substantially: designs will carry a sizable body of machine-interpretable information in addition to the design itself and that information will be used to check design modifications to ensure that the new design does not defeat some goal accomplished by the original design.

Future Work: We are building prototype capabilities for understanding sketches, for understanding verbal and gestural explanations of behavior, and for inferring behavior from diagrams of structure. As these individual capabilities become sufficiently powerful, they must be integrated into an overall system, to enable understanding and interpretation of design and designs sketches to be supported by a wide variety of knowledge sources and inference methods.

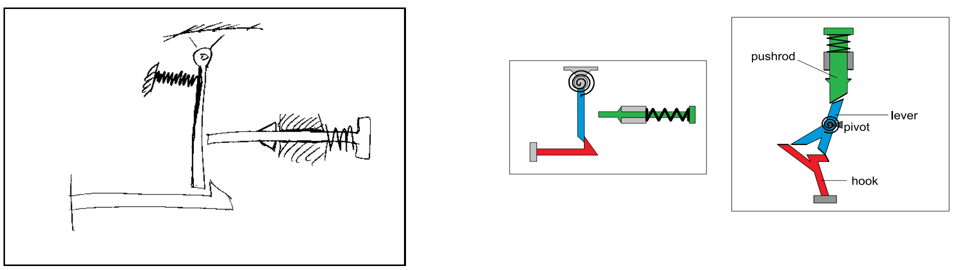

Figure 1: A sketch and some of the designs that result.

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References:

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