Intelligent Mechanical Engineering Design Environment: From Sketching to Simulation

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The Problem: Interfaces to mechanical design systems seriously limit the user's creativity, while drawing on paper does not allow the user to interact with her sketch as a mechanical system. We would like to provide a natural environment for sketching and developing mechanical systems directly on the computer. We are doing this by building an environment that combines the creative freedom of freehand sketching with the technical feedback of viewing and running the sketch as a 2D kinematic simulation.

Motivation: The tradeoff between the ease of drawing a mechanical design on paper and the power of representing it on a computer is too great. The unnatural feel of CAD and simulation software inhibits the design process, so engineers design with pencil and paper, rarely transferring their designs to the computer until they are almost complete.

An engineer should be able to sketch directly onto the computer, having it feel as natural as sketching on paper, while being able to test the design through simulation at all parts of the design process. The computer should keep track of the engineer's actions and intentions, not only interpreting the sketch as she draws, but also recording the design process by asking intelligent questions as she sketches.

Previous Work: Several others have experimented with systems that allow users to sketch designs directly onto the computer. Gross has developed the Electronic Cocktail Napkin–a system for sketching conceptual designs on the computer [5]. The initial sketches, he claims, can be essential to understanding the reasoning behind a design [3]. Pursuing a different domain, Landay describes a system for drawing user interfaces [6]. Forbus describes a multi-modal system for sketching military planning diagrams [4].

Handling ambiguity in the input is another problem we face in building an interactive sketching system. Mankoff has directly addressed the problem of ambiguity in recognition-based systems [7].

Other important work upon which our system is built is the low-level sketch interpretation system built by Weisman and Muzumdar [8]. Finally, More details about the work described in this abstract can be found in [2] and [1].

Approach: Our sketch tool allows the user to sketch and simulate mechanical systems. While the user sketches, the computer watches, updating its understanding of the sketch as a mechanical system, all the while keeping the user informed of its understanding and giving the user an easy means of fixing any misinterpretation.

One difficult aspect of building a sketch interpreter for mechanical drawings is trying to fill in the details often left implicit in the sketch because the viewer is assumed to have a degree of physical common sense. The result is abundant ambiguity – lines in a sketch can represent edges of bodies, rods, parts of gears, or any number of other parts.

As the engineer draws, the computer incorporates each new piece of the drawing into its internal representation of the drawing as a mechanical system, using new elements in the sketch to help resolve ambiguities about earlier pieces. We use a three-stage interpretation process after each stroke the user draws. In the first stage, the computer generates all possible interpretations for the stroke. For example, a circle might be a pivot joint, a mechanical body, or a selection gesture. In the second stage, the system applies knowledge of mechanical engineering as well as knowledge of how people draw to rank the possible interpretations. In the final stage the system chooses the most likely interpretation for the user's stroke and displays that interpretation to the user.

At any point in the drawing process the user can run a simulation of the device drawn. The sketch understanding

program hands off its interpretation to a mechanical simulation system, producing a real-time animation of the device in action (Figure 1).

Impact: CAD systems are becoming fairly sophisticated, but still focus only on the final stages of a design. By integrating sketching and simulation we want to encourage engineers to use the computer earlier in the design process, opening up many possibilities for capturing the reasoning behind a design as the engineer works, rather than trying to get the engineer to record her thought process after the fact.

Because the user is developing her system on the computer in conjunction with a simulation tool, the user can run simulations of her design earlier in the design process. Seeing the simulation, rather than having to visualize it, helps to avoid unexpected and unwanted side-effects in behavior before they become embedded in the system.

Future Work: We plan to continue to expand the capabilities of this system. We will work at incorporating more understanding of behavior into the simulation part of the system, including using behavior models to resolve ambiguities inherent in the sketch. We will also embed design rationale capture capabilities into the system so capturing the motivation and the explanation behind the design will be no more trouble to the user than capturing the design itself.

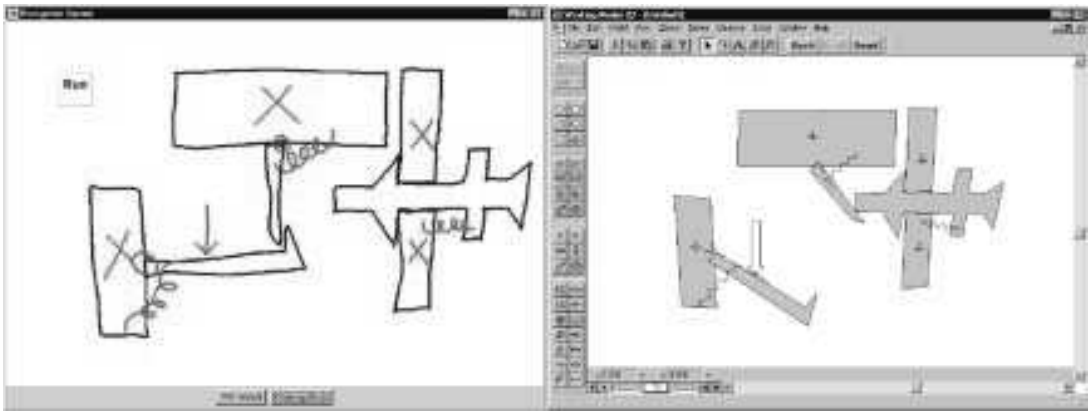

Figure 1: The user draws the sketch of the circuit breaker (left). When she clicks the run button, she sees a simulation of her sketch (right).

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