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 freehand drawing does not allow the user to interact with his sketch as a mechanical system. We would like to provide a natural environment for sketching and developing mechanical systems. 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 their 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 he draws, but also recording the design process by asking intelligent questions as he sketches.

Previous Work: Mark Gross has recognized the importance of sketching in design, emphasizing that drawing in design is more natural and allows for more creative freedom. The initial sketches, he claims, can be essential to understanding the reasoning behind a design [2]. He has developed the Electronic Cocktail napkin–a system for sketching conceptual designs–which incorporates his ideas on sketching in design [3].

Other important work upon which our system is build is the low-level sketch interpretation system built by Luke Weisman and Manoj Muzumdar. It recognizes basic and more complicated shapes, including several mechanical objects, and provides simple methods to work with the shapes once they are recognized [4, 5].

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.

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.

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.

Difficulty: 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– and information that must be filled in by inference, e.g., a certain force and length for a spring may be required by the desired behavior, but were not made explicit in the drawing.

Providing the user with clear and unobtrusive feedback for the system's interpretation is another challenge. Our system modifies the user's strokes as she sketches to indicate its interpretation for the sketch. However, this character of this modificiation needs to be carefully chosen, or it will interrupt the user's sketching process.

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 his thought process after the fact.

Since the user is developing her system on the computer in conjunction with a simulation tool, the user can run simulation 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.

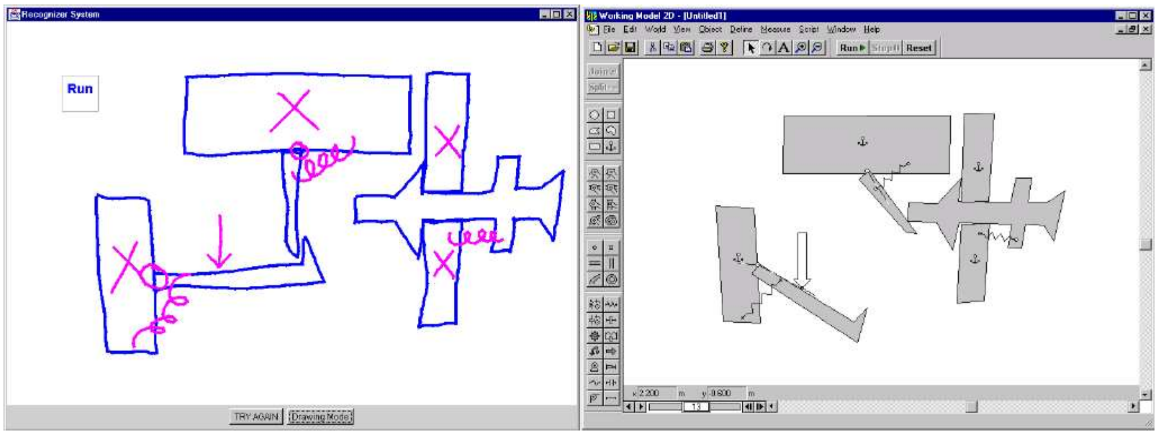

Figure 1: The user draws the sketch of the circuit breaker (left). When she clicks the run button, she sees a simulation of her sketch (right).

Research Support: This work is supported in part by the Ford/MIT Collaboration, under the Virtual Engineering Project, in part by the Lockheed Martin Space Operations Company under the CSOC Contract NAS9-98100, and by the MIT Oxygen Collaboration.

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