

Intelligent Mechanical Engineering Design Environment: From Sketching to Simulation

Christine Alvarado & Randall Davis

Artificial Intelligence Laboratory
Massachusetts Institute Of Technology
Cambridge, Massachusetts 02139

<http://www.ai.mit.edu>



The Problem: Interfaces to mechanical sketch 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 designing mechanical systems that combines the creative freedom of freehand sketching with the feedback of watching the sketched device in simulated operation.

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, driving engineers to work with pencil and paper, rarely transferring their designs to the computer until the designs are completed.

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 phases 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 capturing some of the the design process by asking intelligent questions as the sketching proceeds.

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.[1] He has developed the Electronic Cocktail napkin—a system for sketching conceptual designs—that incorporates his ideas on sketching in design.[2]

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 both basic geometric shapes and drawings of a set of basic mechanical objects, and provides simple methods to work with the shapes once they are recognized.[4, 5]

Approach: Our sketching tool allows the user to sketch and simulate simple mechanical systems. The system monitors the user's sketching, updating its interpretation of the sketch as a mechanical device. The system keeps the user informed of its view of the sketch, if necessary asking the user for clarification. The system is recording and interpreting the sketch in real time, allow it to record design decisions made by the engineer.

As the engineer draws, the computer interprets each new piece of the drawing as part of the mechanical system. New pieces in the sketch can help resolve ambiguities about earlier pieces; making intelligent interpretation of the drawing possible with little disturbance to the user.

At any point in the drawing process the user can run a simulation of the drawing by either clicking a run button or telling the system verbally. The sketching system hands the interpretation of the drawing to an off-the-shelf mechanical simulator, which then provides an animated simulation of the device's behavior.

Difficulty: Sketches are highly informal, as well as incomplete, inconsistent, and at times ambiguous. They also require considerable interpretation by the viewer. Hence one difficult aspect of sketch interpretation is trying to fill in the details missing from a sketch. For example, lines can represent edges of bodies, rods, parts of gears, or any number of other parts, while in order for a device to work, its springs need to have a certain force and neutral-point, neither of which is typically explicit in the drawing.

Sketches are also difficult to simulate because of their informality: Two bodies that are supposed to be touching in a mechanical design may have been drawn with just a little space between them, which can cause unexpected and unintended movements in the device. A human looking at the sketch knows what was intended; we are working to produce programs that behave in the same way.

Impact: CAD systems are becoming fairly sophisticated, but they still focus on the final stages of design. By integrating sketching and simulation we encourage engineers to use computational tools earlier in the design process, opening up many possibilities for aiding the design process and capturing design rationale as the engineer works, rather than after the fact.

The integration of sketching and simulation allows the user to simulate the device much earlier in the design process, allowing the user to avoid unexpected and unwanted behavior much earlier in the design process.

Future Work: We are working to incorporate understanding of behavior into the simulation part of the system, including using behavior models to resolve ambiguities inherent in the sketch. We are also embedding 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.

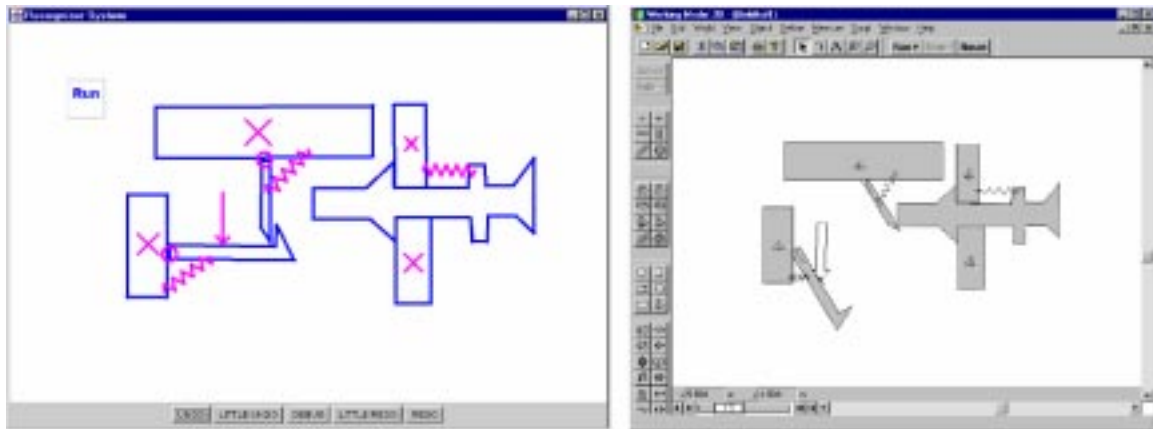


Figure 1: The user draws the sketch of the circuit breaker (left). When she clicks the run button, she sees a simulation of her sketch (right).

Research Support: This work is supported in part by the Ford/MIT Collaboration, under the Virtual Engineering Project. Additional support comes from DARPA under contract number F30602-94-C-0204, administered by Rome Laboratory, for work on the “Intelligent Room.”

References:

- [1] M.D. Gross. Recognizing and Interpreting Diagrams in Design. *2nd Annual International Conference on Image Processing*, pp. 308-311, 1995
- [2] M.D. Gross. The Electronic Cocktail Napkin—a computational environment for working with design diagrams. *Design Studies*, vol. 17, no. 1, 1996
- [3] M.D. Gross and E. Do. Ambiguous Intentions: a Paper-like Interface for Creative Design. *Ninth Annual Symposium for User Interface Software and Technology*, pp. 183-192. Marc Brown and Ramana Rao (eds.), Seattle, 1996.
- [4] M.D. Muzumdar ICEMENDR: Intelligent Capture Environment for Mechanical Engineering Design. Master’s Thesis, MIT, 1999.
- [5] L. Weisman A Foundation for Intelligent Multimodal Drawing and Sketching Programs. Master’s Thesis, MIT, 1999.