Intelligent Mechanical Engineering Design Envoronment: From Sketching to Simulation

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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 developing mechanical systems by building an environment which 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; therefore, engineers design with pencil and paper, and rarely transfer their designs to the computer until those 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 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 in 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 Coctail napkin–a system for sketching conceptual designs–which 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 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:

The our sketch tool allows the user to sketch and simulation mechanical systems. While the user sketches, the computer contantly watches what the user is doing, constantly updating its view of the sketch as a mechanical system. The computer constantly keeps the user informed of its view of the sketch, and asks the user for clarification when it gets confused. Because the system keeps up with the design process it will be able to record design decisions made by the engineer.

As the engineer draws, the computer incorporates the new piece of the drawing into its internal representation of the drawing as a mechanical system. New pieces in the sketch can help the computer resolve ambiguities about earlier pieces; intelligent representation of the drawing is achieved with minimal disturbance to the user

At any point in the drawing process the user can run a simulation of the drawing either by clicking a run button or by telling the system verbally. At this point the system will evaluate the behavior of the system and give the user a smooth, logical simulation of what he has drawn.

Difficulty:

One difficult aspect to building a sketch interpreter for mechanical drawings is trying to fill in the details which are inherantly missing from a sketch. Lines in a sketch can represent edges of bodies, rods, parts of gears, or any number of other parts. A spring has a certain force and length associated with it which is not explicit in the drawing.

Simulating a system in a sketch in a logical way poses another challenge. For example, two bodies which are supposed to be touching in a mechanical design, may have a little space between them when represented as a sketch, causing unexpected, and unintended movement within the system.

Impact:

CAD systems are becomming fairly sophisticated, but they still focus only on the final stages of a design. By integrating sketching and simulation we encourage engineers 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 devoloping 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, she avoids 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.

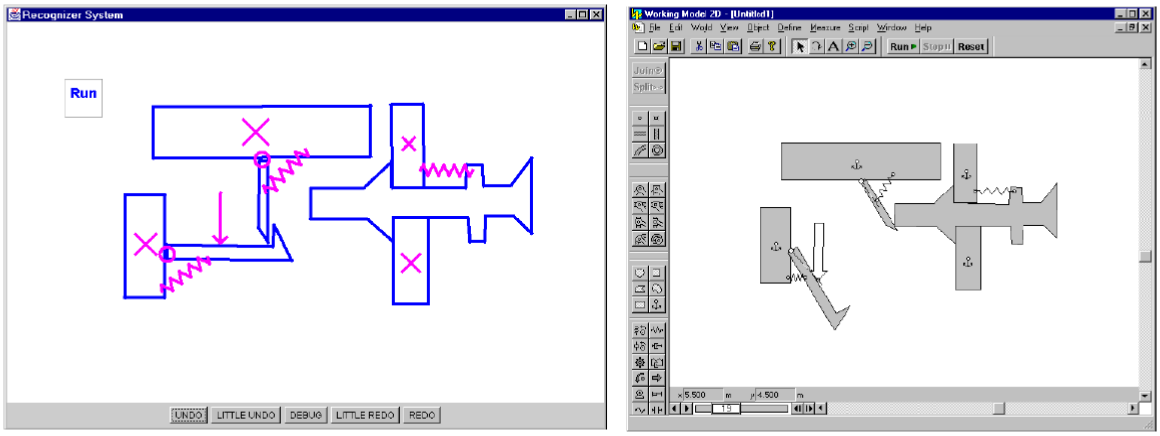

Figure 1: The user draws the sketch of the circuit breaker (left). When she clicks the run button, she sees a simulation of her sketch (right).

Research Support:

Our research has been supported by a bunch of people. I am just putting this line in here because I need to get a feel for how long this section should be. I don't know exactly who to reference yet. But I want to know how long this paragraph can be without making the document spill onto three pages.

References:

[1] M.D. Gross. Reocgnizing and Interpreting Diagrams in Design. *2nd Annual International Conference on Image Processing*, pp. 308-311, 1995

[2] M.D. Gross. The Electronic Coctail Napkin–a conputational 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.