

The Power of Touch

Georgia Tech researchers engineer an old-fashioned "touch" into modern electronic controls.

© Researchers are exploring applications for the emerging field of haptics — the “feel” associated with operating a mechanical device, such as an automobile, aircraft or earth-moving equipment.

Associate Professor Imme Ebert-Uphoff, left, and graduate student Paul Bosscher examine a mock-up illustrating the unusual kinematic ability of an array of joints that could create a “formable crust” of Digital Clay — a type of computer-aided design that is worked in three dimensions like modeling clay.

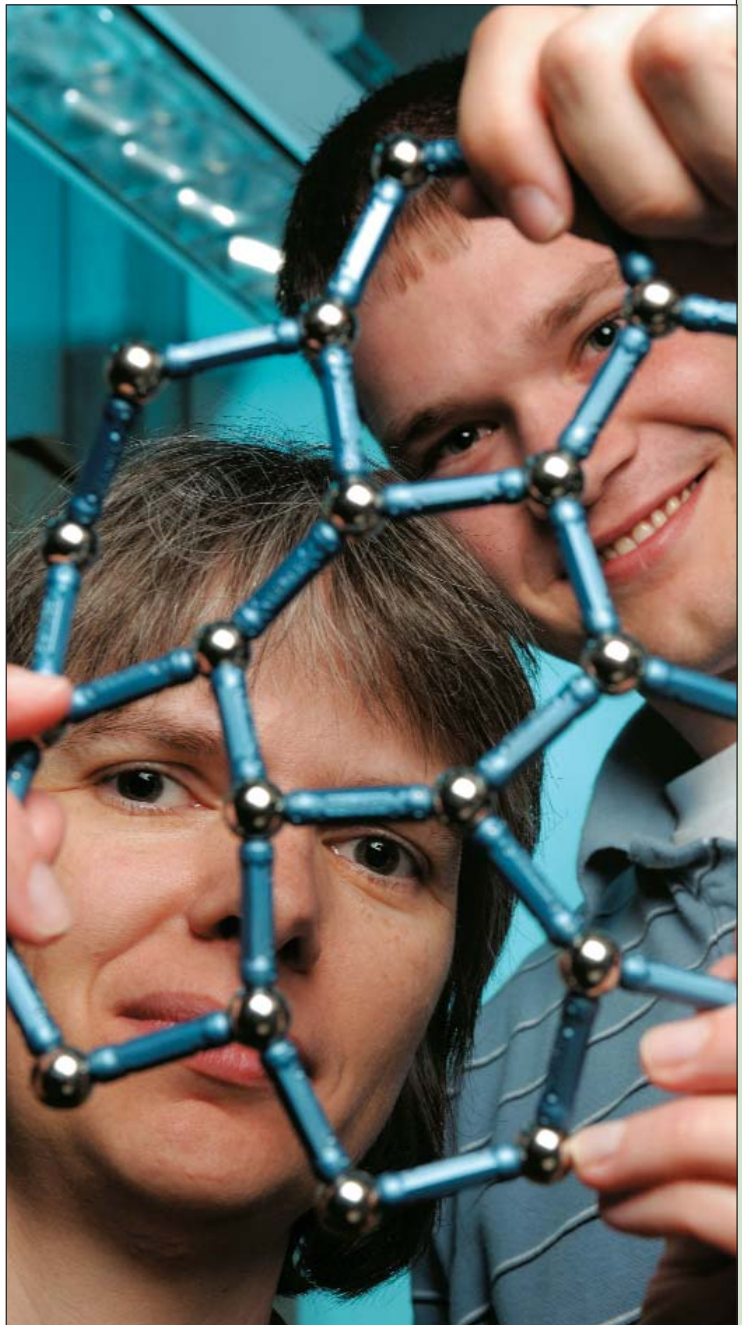
He calls it “playing in the dirt,” but the excavations dug by Wayne J. Book and his graduate students represent serious work.

Book, a professor of mechanical engineering and the HUSCO/Ramirez Chair of Fluid Power and Motion Control at the Georgia Institute of Technology, heads a research team exploring applications for the emerging field of haptics. Haptics is familiar to everyone even if the word is not. It’s the “feel” associated with operating a mechanical device, such as an automobile, aircraft or earth-moving equipment.

“Haptics is focused on your kinesthetic senses, the forces you feel in your joints and muscles as you move your body and the way the environment reacts to that motion,” Book explains.

Haptic feedback is a natural byproduct of manual controls and helps an operator know more about the environment in which a machine is operating, as well as its performance. Modern electronic controls, while easier to use, have eliminated useful haptic sensations, Book notes.

BY GARY GOETTLING
PHOTOGRAPHY BY GARY MEEK



“People need that feel, that connection, with the vehicle they’re operating”

— **Wayne J. Book**, professor of mechanical engineering, describing the need for haptic controls

Professor Wayne J. Book, foreground, heads a research team exploring applications for the emerging field of haptics. Haptics is the “feel” associated with operating a mechanical device. In the background, graduate student Matthew Kontz, center, and research engineer James Huggins run the haptic backhoe.

As an example, he cites early models of automobile power steering and power brakes, which were nearly devoid of haptic response. Automakers realized they had to modify those systems to include haptics “because people need that feel, that connection, with the vehicle they’re operating,” Book adds.

He and his students are applying this principle in their design of haptically enhanced controls for backhoes. The project has developed primarily on desktop computers with sensors networked to haptic interfaces and electrohydraulic actuators.

Researchers believe programming haptic forces into the electronic control system can make a device more intuitive, and therefore faster to learn and easier to operate. Also, operators could avoid

potential hazards if their controls provide haptic feedback.

“You can provide cues through your sense of touch that you’re getting close to a water, gas, electric or communications line by feeling resistance or whatever other kind of response you want to code into the control mechanism,” Book says.

Book’s students have been digging holes on the Georgia Tech campus with a backhoe to identify both human and mechanical operational nuances in a real-world setting.

“A backhoe’s natural environment is not a very controlled environment, so this is a bit of a new ballgame for a mechanical engineer because we’re working with

the big variable of the human operator,” Book says. “We need to do repeated tests to determine what constitutes average behavior.

“At the same time, every time we do those tests the ground is a little different,” he adds. “So we have these two variables, and it’s a challenge to separate their effects.”

The operations data then can be matched with appropriate haptic responses programmed into the controls so a button or lever conveys by its feel to the operator what the equipment is encountering. The final product conveys the responsiveness similar to a video game, but enhanced with haptics.

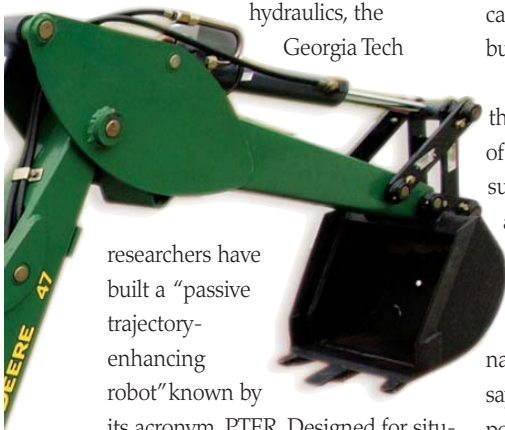
The backhoe-control project is supported with equipment and funding from a number of companies including John Deere, Sauer



Danfoss, Balluff, WIKA, Hydac, HUSCO, Ford Motor Co. and the National Fluid Power Association.

It follows a similar effort by Book's group to enhance forklift control. The researchers outfitted a laboratory-scale hydraulic lifter with a commercially available haptic interface connected to proximity sensors up front. The sensors trigger the feel of a wall, allowing the operator to pick up loads gently and precisely, Book explains. Additional haptic sensations accompany the vehicle's movement and how closely its vertical and horizontal movements follow control commands.

In another approach to the practical application of haptics to hydraulics, the Georgia Tech



researchers have built a "passive trajectory-enhancing robot" known by its acronym, PTER. Designed for situations where humans interact directly with hydraulic machines, such as exercise equipment, PTER imparts high resistance when the device is being used improperly and lower resistance when it is used correctly. In effect, the varying levels of resistance guide the proper use of the machine.

Moreover, the haptic interface and special hydraulics provide a high degree of safety.

Also taking shape in Book's laboratory is a device he calls "Digital Clay." It is a type of computer-aided

design that is worked in three dimensions like modeling clay. Think of the specialty-store conversation piece that consists of hundreds of pins suspended closely together in a frame. Pressing your hand lightly on top of the pins produces a hand image on the other side of the frame.

Similarly, researchers are attempting to produce a 3-D computerized display that is responsive to touch. The project, in year three of a five-year effort funded by the National Science Foundation, could provide industrial designers with an intuitive new tool.

On a typical computer screen, "you have limited degrees of freedom with an object," Book explains. "You can rotate and roll it, move it around, but that's it."

Digital clay is a haptic surface that displays all of the 2-D attributes of an object with added features — such as texture and hardness — associated with shape.

"In designing a particular shape, you want to experience that shape and be able to describe it in a more natural way to the computer," Book says. "The object is not just a fixed position. If you want to display it as a soft surface you can have it respond by yielding when you push on it. If you want to display a hard surface, you have it yield only slightly or not at all."

So far, the work has resulted in a 100-cell square grid that responds to shape commands. Future plans are to expand the size of the grid significantly while increasing resolution by moving the cells closer together from the present 5-millimeter spacing to about 3 millimeters, Book explains.

"Maybe you want to design a golf course," he continues. "You

push on the display to give your fairway a certain slope. If you push too far and make an erosion hazard or some construction difficulty, the computer will tell you through feel that you've gone a little too far there. You'll feel resistance to changing the shape any further."

Hovering over the technical challenges of haptics research is the issue of cost.

In the case of backhoes and forklifts, equipment could be retrofitted with new valving arrangements that are easier to control haptically, but very expensive, Book says. His approach is to build haptic adaptations from the electronics side of the process.

"We are trying to work with economically viable components and enhance their performance with computer control," he says. "Computers have a tremendous cost-benefit ratio that's improving all the time."

The Tech research team also devotes time to documenting the improvements brought by haptic control — fewer accidents and increased productivity.

But even reasonable cost may not sell haptically enhanced machines in a world of veteran heavy-equipment operators.

"On the other hand," Book says, "people who have grown up playing video games are probably much more agreeable to working with a new haptic style of controller rather than spending many months learning how to operate a conventional control."

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— Wayne J. Book, professor of mechanical engineering, on the prospects for haptic controls

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