Giving Engineers the Magic Touch

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Diana Phillips Mahoney

In the manufacturing world, interactive digital mockups are beginning to supplant full-scale physical mockups as a medium for assessing the form, fit, and function of a new product`s components before mass production. The primary advantage of such an approach is that it fosters a more cost- and time-efficient production process. It`s easier, for instance, to implement changes to a digital model than a physical one. And the ability to share a digital model among all the people who have a stake in the final product enhances communication among the group early on, thereby reducing the likelihood of last-minute overhauls. Digital models can also be used for various other purposes, including internal and external communications and training for assembly and maintenance. Perhaps even more intriguing is the idea of presenting the digital mockup in a fully immersive virtual setting, so users can manipulate the virtual model in much the same manner as they would its physical counterpart in the real world.

Unfortunately, one stubborn technical hurdle stands in the way of full exploitation of digital-mockup technology: the absence of realistic force-feedback sensations to simulate physical interaction with the digital data. Though not critical for marketing and presentation applications, realistically re-creating the sense of touch can be especially important to certain design, maintenance, and training applications, in which many tasks could be streamlined through full sensory engagement. With a haptic-interaction system, for example, designers would be able to evaluate potential product-assembly sequences using their natural mechanical skills rather than a complex user interface. Additionally, in maintenance applications, the ability to feel a part as it`s being removed from an engine--and feel it collide with surrounding parts--would let engineers determine the best paths of entry and exit.

Until recently, the advantages of "industrial haptics" existed mostly in discussions of its potential. In fact, it has only been in the past few years that the ability to simulate realistic force-feedback has made its way to the commercial market. The advent of such tools has led researchers in the computer visualization lab at the GE Research and Development Center (GE CRD) in pursuit of an industrial-haptics solution. To this end, the group is working with haptic-device manufacturer SensAble Technologies to develop specialized control software for industrial applications.

"Specifically, we`re trying to simulate the physical interaction of one part with one or many other parts," says Ricardo Avila, a researcher at the Center. "There are certainly ways right now that you can simulate part removal and replacement without haptics. But they involve time-consuming analyses, possibly taking up to a couple of days. In a haptics environment, those types of analyses can be done in under an hour."

The Center`s "customer" for this project is the GE Aircraft Engines division developing the F120 engine for the Joint Strike Fighter application. One of the primary objectives of the project, says Avila, "is to bring folks with a maintenance background into the CAD world, but enable them to work in that environment the way they`re used to working--with their hands.

"Expensive physical mockups used to be accessible to large numbers of people, including maintenance people, who could take a look at a new design, try things out, and comment on it," says Avila. "One of the tradeoffs we made when we went to this purely digital world was that these people were sort of shut out. They could see the designs on screen, but they couldn`t get their hands on them." Another drawback is that although automated maintenance-analysis operations have been implemented to try to determine the best way of removing and replacing parts, he says, "algorithms won`t make the same mistakes a human makes. So we have to be aware of the potential for such mistakes. We want to give the design engineers the opportunity to use their knowledge of the domain while doing maintenance-analysis studies."

The biggest challenge the group faces is calculating collision detection and force at the refresh rates required for haptics, approximately 1000 per second. "Imagine trying to calculate the intersection of a 10,000-polygon part with a 100,000-polygon obstacle course in 1/1000 of a second, not to mention calculating the force," says Avila. Because of the practical impossibility of this given the current state of technology, the GE team is building computational models to approximate the force and collision sensations incurred during object manipulation. Just as animators and designers often build lower-resolution visual representations of objects in order to move through large geometric representations, the GE researchers are building low-resolution haptic representations. As with visual displays, says Avila, "we try to keep the detail in places where it`s important and lessen it in places where it`s not so noticeable." The first step in the process, he says, is determining what the lowest level of acceptable detail is, then modifying the algorithms and data structures to accommodate the predefined haptic constraints.

Handing Out Feedback

The researchers are using SensAble`s Phantom force-feedback device. With it, users manipulate a handle, at the tip of which they feel the effect of translation and rotation. "You don`t use two hands, and you don`t feel forces on your elbow or anywhere else, but you do have this one-grip location that can represent a part or a tool," says researcher Steve Linthicum, who moved to the R&D Center from GE Aircraft Engines to provide first-hand feedback on the system`s design. Aircraft engineers can use the haptic device as a wrenching tool, for instance, to analyze wrench access, or it can be used to represent a component on the outside of the engine. Clearly, notes Linthicum, "we`re not at the point where you feel all the forces you would feel if you were working on an engine--you don`t feel your knuckles hitting on anything and you don`t get the tactile feedback of, say, the surface of an actuator on the engine. But you will feel what it feels like when the actuator bumps against geometry."

"Right now, this tool is just another piece of the puzzle to help engineers become more efficient in design development and analysis in the digital environment," says Avila. "The biggest payoff will come down the road in training applications, especially when you`re training people on different configurations of the same basic engine. You won`t have to keep multiple iterations of certain engines around in a training-school environment. Instead, you`ll be able to train users in this visual, haptic, potentially immersive environment, and the students will still get the "hands-on" experience they need."

The industrial-haptics system runs on a standard dual-processor Pentium-class machine (one of the two processors is dedicated to the haptic interaction). The first version will be in the hands of aircraft engineers later this summer. According to Avila, the engineers plan to begin using the system immediately to generate production analyses. This version of the system will be "very useful" on its own, he says, and it will also serve as the first stepping stone to further development. "The engineers will give us feedback about what works for them and what doesn`t. We`ll learn how they put the system to practical use in a design environment."

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