Fit for a King

Computer scanners capture the body's subtle shapes

By RICHARD LIPKIN

In the classic comedy film *Sleeper*, a futuristic Woody Allen pays a visit to a 21st century tailor, who happens to be a robot.

"You vant jackets, ve got jackets. You vant trousers, ve got trousers," says the heavily accented computer-clothier. "Step in here," the robot says, motioning Allen into an automated tailoring machine. Lights flash, the machine hums, a computer measures the red-haired time traveler, and out pops a suit, which Allen puts on.

"This is terrible," Allen balks, pointing to his baggy outfit.

"All right, all right," mumbles the robot, "Ve'll take it in a little."

As is often the case with science fiction, life is proceeding to imitate art—but this time, with better-fitting results.

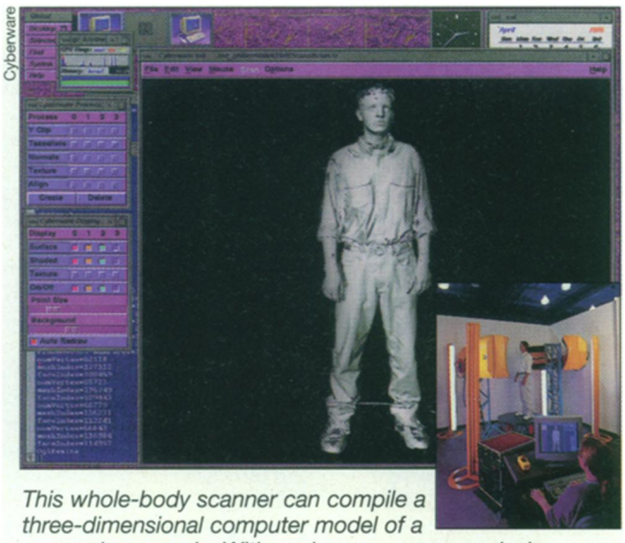
Researchers are designing systems that can scan the surface of a person's body and produce an accurate three-dimensional image of it. These scanners offer the possibility of crafting quick, computerized representations that can be used to design a wide variety of items, from custom-fit clothing and shoes to automobile passenger compartments and crash helmets.

Since the 3-D scans employ a general process that works for virtually any spatial object, researchers around the country are also seeking to adapt it to other purposes. "People are looking at ways to use this technology for biomedicine, anthropology, archaeology, museum inventory, and entertainment," says David Addleman, president of Cyberware, a computer graphics firm in Monterey, Calif.

To obtain a 3-D image for fitting clothes, a customer puts on a stretchy, tight-fitting garment and steps onto a platform surrounded by an array of lights and mirrors. The system passes harmless laser beams over the person's body from head to toe, while cameras record the patterns they make. The system can then put together a detailed surface map of the individual's shape in a process that takes only 17 seconds.

"The system shines stripes of light across a person, then measures the distortions created by the body's curves," says Addleman. "With four video cameras and four mirrors, the machine has eight views of the person. By viewing the person from different angles and perspectives, we can triangulate points on the body surface."

The result is a grid, looking something like a mannequin made of wire mesh, assembled from 300,000 to 400,000 points spaced 3 millimeters apart. Once the scanner has assembled a "cloud of points" covering the surface of a person's body, the computer then "stitches" the various views together to create a single, seamless 3-D likeness, Addleman explains.



This whole-body scanner can compile a three-dimensional computer model of a person in seconds. With such scans, one can design equipment, fashion uniforms, or fit everyday clothing.

The basic concept of the technology is simple, he adds. "You're really just mapping a curved surface in space." The tricky part, Addleman says, "is putting it all together" to create a smooth, accurate, and detailed figure from which information can be extracted to fit clothing or make masks and helmets, for example.

The idea of the scanner arose in a military project aimed at finding a way to produce faster, cheaper, and better-fitting uniforms for troops, says Kathleen M. Robinette, an anthropologist at the Wright-Patterson Air Force Base in Ohio. "Traditionally, we measure people with very basic tools, like tape measures and calipers," she says. "But they don't provide complete or accurate information. In the end, most of the information used to design clothing comes from an artist's imagination."

Standard measuring tools take too much time to use, she adds. It can take as long as 20 minutes to measure someone properly for a garment, so military scientists decided to try to computerize and automate the body-measuring process. "We started out using scanning machines to measure people's heads and faces for helmets," she says. "Eventually it became feasible to use the same methods on the whole body."

The Army and Air Force are already using the body data to make a smaller number of uniforms, boots, and flight suits fit a wider range of body types.

"We've been approached by podiatrists and shoe companies wanting to make scans of people's feet" for custom-fitting shoes and orthotics, Addleman says. Scans of hands could serve in the design and fitting of gloves.

In one new venture, Jeffrey Silverman, owner of the Custom Foot shoe store in Westport, Conn., orders footwear made to fit electronically scanned feet. Using a simpler scanner than Cyberware's, Silverman models his customers' feet, then transmits the data by modem to Italy, where manufacturers produce customized versions of existing models. Purchasers receive their uniquely fitted shoes in about 2 weeks, at an average cost of $140 per pair, Silverman says.

Physicians at the Department of Veterans Affairs are looking at ways to use the 3-D scanner to make replicas of body parts. A person who loses an arm or leg, for example, can have the remaining one scanned into the system. The computer can then invert the model to make a mirror image of the existing limb—a process that could streamline the making and fitting of prostheses.

The Army and Air Force are applying the new technology to design better aircraft cockpits, parachute harnesses, and other safety equipment. "These data are good for designing anything a body has to fit into," Robinette says. "You can rotate the image, look at it from different angles, even change aspects of the figure," she says.

In similar fashion, scientists concerned with improving safety in the workplace want to use the scanning system to lessen the likelihood of industrial accidents. "There's very little accurate data on the body dimensions of certain popula-

tions, such as construction and agricultural workers," says Hongwei Hsiao, a biomechanist at the National Institute for Occupational Safety and Health (NIOSH) in Morgantown, W. Va. "We're hoping to use these machines to gather information to design better protective equipment, such as face masks, eyewear, harnesses, and respirators. We can also study problems like the compression forces that cause lower back injuries in people who have to carry heavy loads. The more we know about human shapes and sizes, the better we can do in designing safety features for vehicles and equipment to reduce deaths and injuries."


Deason *et al.*/Idaho National Engineering Laboratory

Using the system to scan dinosaur bones into a computer, scientists can more easily fabricate scale models of the fragile bones.

Taking advantage of the system's ability to scan bones accurately, archaeologists are using the device to construct replicas of dinosaur skeletons for museums. "There's often a problem at archaeological sites of finding incomplete skeletons of animals," says Vance A. Deason, a physicist at the Idaho National Engineering Laboratory in Idaho Falls. "The original bones are fragile, and you only have a few of them."

Thus, to create the mighty skeletons on view at most museums, archaeologists must mold and model each bone, then fit the bones together. The original fossils remain safely in storage, while the giant skeletal replicas—often assembled from copies of pieces of several incomplete skeletons—stand in view of awestruck patrons.

"The problem in combining the bones to make one complete skeleton is that bones are often taken from animals of different sizes, so they have to be scaled properly to fit together," says Deason. The process is extremely slow and expensive. "With this technology, you can scan bones into the computer, then scale them to make a perfect replica that's also the right size."

The system could work equally well for other art objects preserved in museums, Deason says. For instance, curators must often protect rare and delicate objects from mass viewing and handling, lest they become damaged. As a result, only scholars are permitted to see and handle some of a museum's finest pieces. A 3-D scanning system capable of producing accurate, color replicas of art objects could permit more people to view and handle at least copies of rare works, Deason says.

Engineers manufacturing objects such as automobile parts might use these modeling techniques to speed up their design and testing procedures. Individuals studying inaccessible architecture or ruins might benefit from calling up replicas of rare items or buildings for detailed study. Even home shoppers, perusing the inventory of a virtual department store on television or a computer, might want to download and inspect models of items they're considering buying.

"We're working on scanning large objects, like cars, sculptures, and buildings," says Marc Levoy of Stanford University. "This would enable someone to create, say, a virtual showroom for automobiles or a movie set or an urban landscape." With such depth and accuracy of detail, someone wearing a virtual reality headset could take a simulated walk or flight through a building, neighborhood, or even city.

"My goal is to scan a historic building and make a model that's so realistic, you could use computer graphics to fly through the model and it would look indistinguishable from a video of the original."

As part of realizing that technological fantasy, Levoy and his colleagues at Stanford have assembled a "responsive workbench," on which one can see and manipulate virtual objects created from 3-D computer models. "If you put on special glasses, the objects look like holograms sitting on the table," says Levoy.

Capitalizing on the scanning system's ability to describe a 3-D object in a digital format, Levoy and his colleagues have built a 3-D fax machine. As a demonstration, they scanned an image of a 6-inch-tall statue of Buddha into the computer, then transmitted the file to another location, where a stereolithography machine recreated the smiling Buddha in plastic. Start to finish, the process took about 18 hours.

In an effort to integrate such technology into the manufacture and retail sales of clothing, scientists at the Textile Clothing Technology Corp. in Cary, N.C., are pursuing a project called "apparel on demand."

"The idea is to automate the designing, cutting, and fitting of garments for retail customers," says David A. Bruner, an engineer at the company. "The long-term goal is mass customization of clothing."

In this vision, customers visiting a retail clothing outlet could, in addition to searching through racks of clothes, flip through pictures in books or on a computer screen to find the items they want. They would then step into an automated measuring booth, which would gather their vital statistics and put the data onto a computer disk or magnetic card. Once they've selected the items of their choice, the retail outlet would transmit the customers' measurements to a factory, where the garments would be cut and sewn to fit their exact body dimensions, then delivered directly to their homes.

"We believe that the whole process, from purchase to delivery at the customer's home, should take 24 to 48 hours," says Bruner.

To make this system feasible, researchers at the company are developing a simpler, less expensive whole-body scanner that can take all necessary measurements in only 2 seconds. To achieve this goal, they're using a laser scanning technology similar to that of Cyberware but with more video cameras to make a quicker, less detailed model. To fit clothing, one doesn't need submillimeter accuracy, Bruner says.

Though starting up such a system requires a large capital investment for the industry, says Bruner, in the long run manufacturers believe that the changeover will not raise the retail price of garments. "The automated process eliminates much of the waste in the existing system," he says.

Currently, about one-third of all mass-produced garments sell at a discount, since manufacturing lags lead to mismatches between supply and demand. Moreover, another 30 percent of raw textiles are never fashioned into garments because they're considered out of style, he adds. Despite the need to add equipment to the present production line, in the long run such an "agile" manufacturing system requires less infrastructure to operate and manage than existing clothing factories do, Bruner says. "That's another cost advantage."

Despite the plethora of mass-produced retail clothes available to U.S. consumers, the data suggest the nation is poorly garbed. According to clothing industry statistics, only half of U.S. consumers fit correctly into off-the-rack garments. Of the ill-clad customers, half alter their clothes to fit properly, while the other half don't even bother.

Based on a survey by Audra Knight and Nancy Cassill, textile specialists at the University of North Carolina, Greensboro, consumers—especially women—are willing to pay up to $10 for body scans to get their clothes to fit properly.

"Based on these estimates," says Bruner, "we believe there's a strong market for customers who aren't served well by the existing system." □