Motion Capture Moves into New Realms

Brett Allan King and Linda Dailey Paulson

When many people think of motion-capture technology, they think of people wearing reflective markers and having their movements captured on camera for use in modeling figures created by animation or computer graphics.

Motion capture is frequently associated with movies or videogames. For example, most of the passengers seen strolling the ship's deck in the movie *Titanic* were created with computer graphics, their movements made lifelike via motion capture. And games such as Electronic Arts' popular *Madden NFL* series use the technology to make characters' movements more realistic.

Now, motion technology is moving in some new directions. Researchers are working on techniques that don't, for example, require placing hundreds of markers on models.

Also, motion-capture applications are becoming less expensive and more readily available. Fields as diverse as medicine, manufacturing, and advertising are thus beginning to utilize the technology more often.

Vendors are also working on motion-based approaches to enable people to use gestures to navigate computerized visual presentations or issue commands to devices.

Globally, although not in the US, nonentertainment motion-capture applications now account for more

revenue than entertainment-related ones, noted Julian Morris, deputy chair and chief technology officer of the Oxford Metrics Group, a leading motion-capture and movement-analysis vendor.

Nonetheless, motion capture still faces challenges, such as output precision and ease of use.

INSIDE MOTION-CAPTURE TECHNOLOGY

Motion capture has been the subject of research for several decades. It has been pursued for its potential advantages in areas besides movie-making. For example, in manufacturing, motion-capture technology places simulated users in virtual products to test them, which is less expensive than placing real people in real products and having to build and rebuild physical prototypes.

Motion-capture displays are also an engaging form of advertising, said John Payne, president of Monster Media, a digital-advertising-technology vendor.

History

Motion capture's first uses, beginning in the mid-1970s, included Polhemus Navigation Services' tool for magnetically tracking military pilots' helmet movements to help them lock in on targets.

The first 3D motion-capture product, delivered in 1980 to the University of West Virginia and Children's Hospital Boston, was the Oxford Instruments Group's Vicon System, which captured images of children's gaits to enable physicians to detect disabilities.

Motion capture wasn't tried in movies until 1990, with the film *Total Recall*. The Motion Capture Society, a professional organization that promotes the technology, considers 1992's *Lawnmower Man* the first live-action movie to feature body-motion capture.

Advances in computer graphics, software, processing power, and algorithms made possible the real-time conversion of raw motion-capture data into either an animated figure or a command, noted Oxford's Morris.

How it works

There are several ways to capture body motion. The *passive optical* approach is the dominant technology, according to Morris. This technique places Ping-Pong balls or other types of markers coated with a reflective material on one or more moving subjects' bodies at joints and other points that are key to identifying motion.

Multiple video cameras with strobes around the lenses provide the light that falls on the markers and then reflects back into the lenses. The cameras capture movements at from 240 to 2,000 frames per second. They then send the information to a computer running software that records various aspects of the motion, including position, angle, velocity, and acceleration. The motion-capture system can import this information as a 3D model for use with animation software.

Other approaches capture body motion by, for example, using LEDs as markers to provide the necessary light to cameras. This represents an *active optical* technique.

Systems also utilize magnetic, mechanical, and acoustic technologies.

Acoustic systems track movement by receiving signals from transmitters strapped to a performer's body. Mechanical systems measure the physical motion of a subject's body. And electromagnetic motion capture uses a central transmitter and sensors to relay the position and orientation of an object's parts as they move, based on electromagnetic field changes.

Motion-capture systems then use software and, occasionally, human intervention to conduct the calibration necessary to make an animated character's movements match the model's captured motions.

Calibration is needed to make motions captured from, for example, a performer's elbow match those of an animated character's elbow. Moreover, multiple cameras capture motion from each point on a performer to create a 3D image. Calibration is necessary to combine the information from different angles into the one image.

A NEW DAY FOR MOTION TECHNOLOGY

Processing power is much less expensive than in the past. Also, cameras, other equipment, and animation software are less costly because of technology advances and increasing demand from movie studios and other users.

Because of improved performance and lower cost, motion-capture technology is finding its way into applications other than movies and videogames.

Sports experts use motion capture to, for example, track golf swings or swimming strokes to improve participants' performance. The technology is also used in motion-analysis research and video surveillance.

Proponents tout technology that captures user movements, identifies the motions, and then utilizes them as a potential navigation tool for computerized visual presentations or for issuing commands to TVs and other consumer electronics.

The US Defense Department has requested research into developing such a technology, said Oxford's Morris.

Gesture Studios, a motion-capture technology provider, is working on the GoodPoint gesture-based device-control system.

Companies are using motion-capture technology in more than just movies and videogames.

Advertising

Advertisers are beginning to use motion technology in innovative ways.

MonsterMedia has utilized the technology in campaigns for clients like Adidas, Lexus, and Target in outdoor advertising in high-traffic areas such as Las Vegas' McCarran International Airport and New York's Herald Square subway station, noted Monster Media's Payne. This is important, he said, because outdoor formats such as electronic billboards and display walls are becoming more significant forms of advertising.

MonsterMedia's MonsterVision ground-, wall-, and screen-based systems help keep consumers focused on the advertising by enabling them to interact with the content being displayed. The systems track passersby's body positions to let them manipulate the items being shown by, for example, brushing away virtual snowflakes to reveal a scene behind them, shooting virtual basketballs, or kicking objects projected onto the floor.

The system operates via a PC or laptop linked wirelessly to MonsterMedia's control center, which monitors the content of screens around the country, gauges performance-related issues such as CPU usage and the strength of projector light bulbs, and updates advertising content.

The system also includes a projector, infrared diodes, and a video camera. Pedestrians move between the projector and display surface, onto which the system emits both an infrared light grid and images.

When the pedestrian moves, the camera detects motion via changes in the infrared grid. The PC- or laptop-based software converts the camera input into structured data for analysis. The software then calculates the user interaction with the virtual objects and displays the appropriate result.

Medicine

Doctors frequently use motion-capture technology with patients to conduct gait analyses that identify walking abnormalities that might indicate the presence of a disease. For example, a child's limp could reflect a disorder such as cerebral palsy or muscular dystrophy.

Related technology is also helping with medical education, in elaborate computer-based surgical-simulation systems. These systems frequently use haptics, the science of applying tactile sensations and controls to interactions with computer applications.

The applications re-create medical situations in 3D virtual-hospital settings, complete with avatars and virtual tools, explained Parvati Dev, director of the Stanford University Medical Media & Information Technologies (SUMMIT) Lab.

Dev and other SUMMIT researchers are improving their Spring real-time, soft-tissue simulation platform for building and running surgical simulators. As Figure 1 shows, Spring provides the virtual world in which the simulations occur.

The system uses haptics technology that creates physical resistance, which lets users working with virtual scalpels or other surgical tools feel like they are cutting or manipulating bone or tissue.

Spring captures user motions mechanically via its haptic tool or another external input device such as a mouse. The input device sends information to a haptic system that processes and sends 3D movement data to the virtual world for viewing, usually via IP connections. The haptic system also operates motors that control the input device's feel.

Enhancing engineering and manufacturing

Some large companies—such as BMW, Caterpillar, John Deere, and Lockheed Martin—that make complex items like jets or cars are using motion-tracking systems to design virtual products without having to build large numbers of expensive prototypes. The technology lets engineers determine how well people would work with proposed product designs.

Ford Motor Co. uses motion capture in both product development and vehicle design, noted Elizabeth Baron, one of the company's virtual-reality and advanced-visualization technical specialists. In addition, Ford utilizes the technology for manufacturing simulations to, for example, cost-effectively design safe and efficient assembly lines, said Allison Stephens, the company's technical leader for assembly ergonomics.

Manufacturers also use the technique to analyze existing assembly lines for inefficiencies.

Face tracking

Used primarily to make animated faces move realistically, face tracking works differently than body-capture technology.

Systems capture body movements via strategically placed markers attached to a subject. This works because the human body moves primarily via its large skeletal structure. Markers don't work as well for tracking faces, where subtle expressions are created primarily via small muscle movements, Oxford's Morris explained.

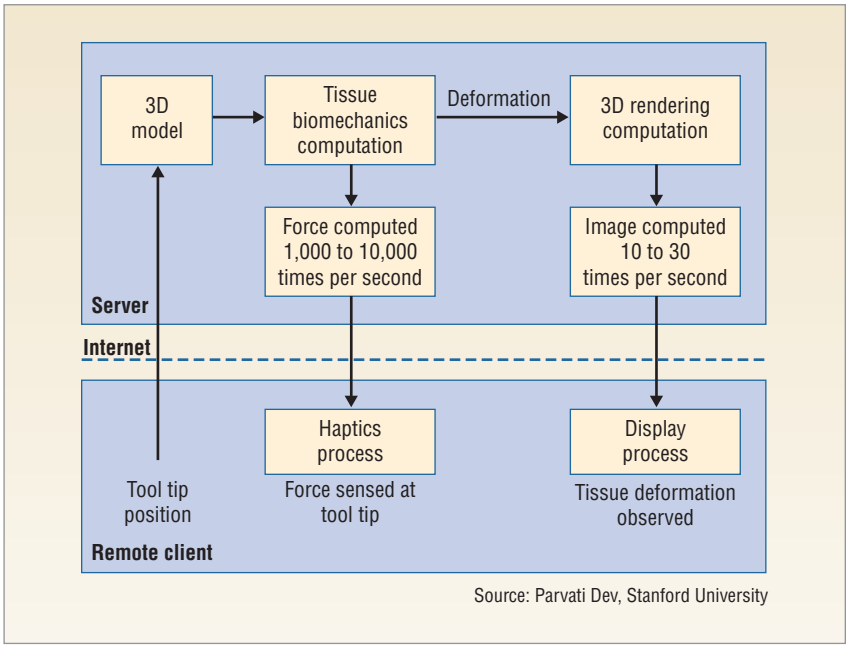

Figure 1. Stanford University's Spring real-time, soft-tissue simulation platform for building and running surgical simulators uses motion capture and haptics. Spring captures user motions mechanically via a haptic or other input tool. The tool sends information to the haptic system, which processes and sends 3D movement data to the virtual world for viewing.

Vicon and vendor Mova are working together on markerless motion tracking. With the Mova Contour System, models apply phosphorescent makeup, which is subject to fluorescent strobe lighting, to their entire face. This enables the capture of a face's motions, yielding a natural surface texture. It also provides a high contrast between the facial surface and the background, Morris noted.

OBSTACLES IN MOTION

Despite improvements, processing speed and price still pose problems for some larger and more specialized motion-capture applications, particularly those that include computationally intensive technologies such as haptics. Smaller, less costly systems will help the market grow because a greater number of small design houses could afford to use them.

Output accuracy is also a challenge, according to motion-capture expert David J. Sturman, who has conducted motion-capture research and worked as chief technology officer for a game developer that used the approach. He is now vice president of technology at Massive Inc., a Microsoft subsidiary that runs a videogame-advertising network.

It is difficult to precisely map and match large numbers of captured motion points to a virtual representation, Sturman explained.

Working with captured data can also be a problem, said Kathleen Maher, analyst and vice president of Jon Peddie Research, a market-analysis firm. The process of modeling and animating characters based on captured motions is complex, although the software for doing this is becoming more effective and less expensive, she explained.

Moreover, because motion-capture systems can be complicated, implementing, configuring, or using them can be a chore. This makes working with them difficult for some smaller organizations with personnel who might not have sufficient expertise or experience with the technology.

In the future, said Stanford's Dev, many more types of medical procedures should be available via motion-capture-based simulations. Currently, she noted, most procedures have not been virtually animated this way.

The long-term goal is to develop systems that can include a specific patient's information, rather than just generic data, to help surgeons rehearse particularly complex operations, she explained.

The long-term goal for motion-capture technology in general is to develop approaches in which users can capture motion by simply pointing a camera at a subject, without using markers, said Sturman. "A lot of the pieces are already in place," he said.

"I think most of the demand will remain in the [advertising, manufacturing], and entertainment industries, with some growth coming from other fields such as sports and medicine," said Maher. "There are no explosions on the horizon, though. We are now following a period of consolidation, and companies are exploring new areas for growth." ■

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